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**EVALUATION OF WIND AND SOLAR
PUMPING SYSTEMS, 1990**

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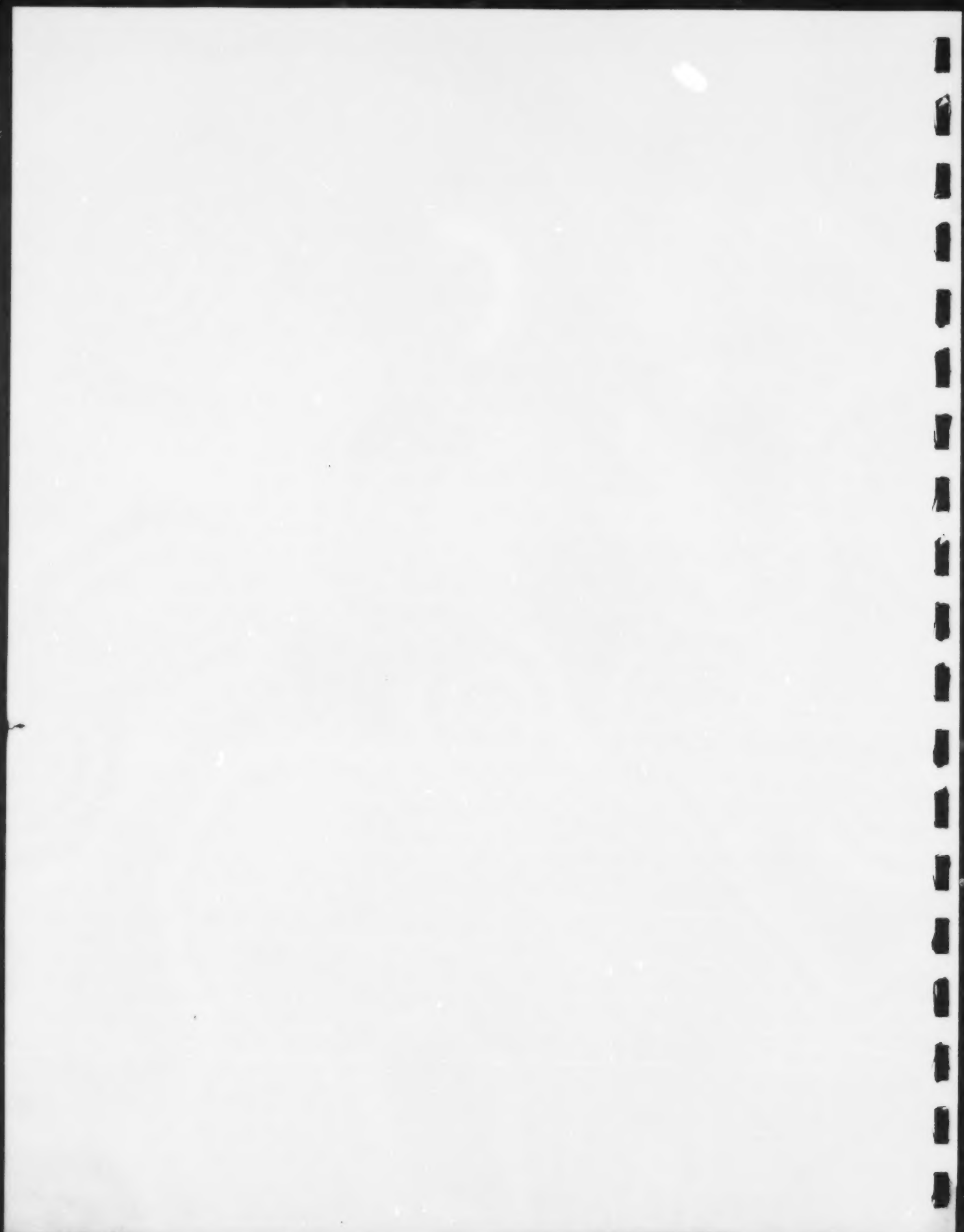
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EXECUTIVE SUMMARY

The Lethbridge Wind Research Test Site was established in 1982 for the purpose of evaluating and demonstrating the use of water pumping wind turbines for local agricultural applications. The test site has since diversified to include solar pumping systems and deep well systems suitable for export markets.

This report presents the results of the tests performed during the 1990 test season. Complete tests were performed on eleven water pumping systems (seven solar systems, four wind systems). Six of these systems were also tested with the Deep Well Simulator. An additional four systems (three wind, one solar) were on the site during 1990 but were either under construction or had failed prior to completion of testing.

The management and funding of the test site underwent a transformation during 1990. The Test Site will now be administered by the Lethbridge Community College (LCC), and managed by the Alberta Farm Machinery Research Centre (AFMRC; a department of Alberta Agriculture). This will provide both an easier method for contract development (LCC) and access to greater testing and evaluation resources (AFMRC). The Southwest Alberta Renewable Energy Initiative (SWAREI) will replace the Alberta/Canada Energy Resources Research Fund as a partial funder of the test site. SWAREI and Alberta Agriculture have agreed to increase their funding support to facilitate the relocation of the test site to the Pincher Creek area. The relocation is planned such that the test site will be fully operational in Lethbridge during 1991 and be replaced by the Pincher Creek site, to be known as the Alberta Renewable Energy Test Site (ARETS), for the 1992 test season. During the 1991 season, some demonstration units will be installed at the Pincher Creek site. The relocation will allow the site to update much of its equipment and increase its public exposure. The LWRTS site was also in danger of having its wind regime corrupted by the construction of nearby warehouses.

The test results during 1990 indicate that there are now Canadian manufacturers of wind and solar pumping systems with products that are commercially feasible from a technical development point of view. There is also an indication that new manufacturers have the capability of reaching this goal. The management and funding changes of the test site will ensure its continued ability to assist manufacturers in their development of reliable solar and wind water pumping equipment.

SOMMAIRE

Le terrain d'essais pour recherches éoliennes de Lethbridge a été établi en 1982 pour faire évaluer et démontrer des turbines éoliennes conçues pour le pompage d'eau aux fins agricoles locales. Depuis lors, le lieu d'essais se diversifie pour comprendre des systèmes de pompage solaires et des systèmes de puits profonds adaptés aux marchés d'exportation.

Ce rapport présente les résultats des essais achevés pendant la saison 1990. Une gamme d'essais complète a été appliquée à onze systèmes de pompage, dont sept solaires et quatre éoliens. Il y en avait six qui ont aussi subi des tests du Deep Well Simulator (simulateur de puits profond). Quatre systèmes additionnels, dont trois éoliens et un solaire, se trouvaient aussi au terrain d'essais en 1990. Les travaux d'une partie de ces systèmes additionnels étaient toujours en cours et d'autres systèmes avaient échoué avant la fin des essais.

La direction et la dotation financière du terrain ont subi une transformation pendant 1990. Dorénavant, le terrain d'essais sera administré par le Lethbridge Community College (LCC) tandis que sa gestion restera avec l'Alberta Farm Machinery Research Centre (AFMRC; une division du Ministère de l'Agriculture albertain). Ainsi seront fournis une méthode plus efficace du développement des contrats (LCC) et un accès élargi à des ressources d'essai et d'évaluation (AFMRC). Le Southwest Alberta Renewable Energy Initiative (SWAREI) remplace le Fonds Alberta/Canada des Recherches en Ressources Énergétiques comme co-commanditaire du site d'essais. Le SWAREI et le Ministère de l'Agriculture albertain entreprennent d'augmenter leur appui financier afin de faciliter le déménagement du terrain d'essais vers la région de Pincher Creek. Le plan du déménagement prévoit que le site de Lethbridge continue en pleines opérations pendant 1991 pour être succédé en 1992 par le site de Pincher Creek, rebaptisé l'Alberta Renewable Energy Test Site (ARETS). Pendant la saison 1991 quelques unités de démonstration seront implantées au site de Pincher Creek. Le déménagement permettra au site de mettre au point plusieurs de ses équipements et d'augmenter son profil public. Le terrain d'essais de Lethbridge court aussi le risque que son régime du vent soit corrompu à cause de la construction des entrepôts avoisinants.

Les résultats des essais de 1990 indiquent qu'il existe actuellement des fabricants des systèmes de pompage solaires et éoliens canadiens qui offrent des produits qui sont rentables du point de vue du développement technique. Il y a aussi des indications que des nouveaux fabricants ont la capacité d'atteindre ce but de rentabilité. Les changements en gestion et en dotation financière portant au terrain d'essais assureront sa capacité continue d'aider des fabricants dans le développement des équipements de pompage solaires et éoliens fiables.

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LETHBRIDGE WIND RESEARCH TEST SITE

1990 FINAL REPORT

1.0 INTRODUCTION

Wind energy was used extensively to pump water for agricultural applications in North America since the 1850's and reached peak usage near the turn of the 20th century. With the advent of rural electrification, the demand for wind turbines declined dramatically. However, with increasing energy costs during the 1970's, interest in using alternate energy again increased and farmers in particular began to look seriously at using wind energy for water pumping applications. In order to provide good technical and economic information regarding the potential use of wind energy in modern times, Alberta Agriculture initiated in 1982, a program of testing and demonstrating commercially available wind turbines for agricultural water pumping applications. In 1987, the scope of the project was expanded to include photovoltaic pumping systems to reflect the growing competitiveness that these systems had attained.

The three main objectives of the study have remained constant throughout the nine years of operation and are:

- 1) Evaluate the potential for wind turbines and solar systems to efficiently pump water for agricultural uses.
- 2) Monitor, demonstrate and evaluate various types of wind and solar pumping equipment developed, manufactured or distributed in Alberta and Canada.
- 3) Maintain a Canadian focal point for expertise in the design, evaluation and application of wind and solar water pumping systems and related technology.

The Lethbridge Wind Research Test Site is located immediately east of the city of Lethbridge, Alberta, Canada. Presently, it is managed and operated jointly by Alberta Agriculture (Lethbridge) and DRB Engineering Consultants Ltd. (Calgary, Alberta). Funding for the Test Site has been provided by a number of agencies including: Alberta Heritage Trust Fund, Alberta/Canada Energy Resources Research Fund, Department of Energy, Mines and Resources Canada, Alberta Agriculture, the Farming For the Future Fund and TransAlta Utilities Corporation.

Mr. R. Atkins, Manager of the Alberta Farm Machinery Research Centre of Alberta Agriculture is responsible for overall management of the Test Site. Mr. D. Baker, President of DRB Engineering Consultants Ltd. is responsible for data collection and analysis and computer systems operation and maintenance. He is also responsible for site design, liaison with wind turbine and solar manufacturers and data analysis related to economics and practical application of collected data. Temporary staff are hired as required to assist with day-to-day operation and maintenance of the site during summer operations.

Numerous publications have resulted from the testing carried out at the Lethbridge Wind Research Test Site since its formation in 1982 (Baker et al, 1989, 1987, 1986; Paterson et al, 1990, 1989, 1988, 1987, 1986). Demonstration days and informal tours are held to educate the public and allow manufacturers to present their machines. The response from these demonstration days and publications has helped to shape the direction and test methods presently found at the Test Site. In 1987, a well simulator was designed and constructed to allow for better evaluation of wind and solar systems at pumping depths up to 250 metres. This will provide needed information for manufacturers wishing to export their machines overseas.

This report describes the results of the testing carried out over the 1990 test season at the Lethbridge Wind Research Test Site. In many cases, manufacturers carried out modifications to their machines during the testing

period. The results presented in this report reflect the latest configuration of the machines located at the Test Site. The test results of each machine are presented as "stand-alone" sections of the report such that they may be better utilized by the manufacturers.

2.0 SITE DESCRIPTION

2.1 Site Overview

The test site is located one kilometre east of Lethbridge and is adjacent to an irrigation canal within the Saint Mary River Irrigation District. The site was selected for the homogeneity of the surrounding terrain and the availability of water for the pumping circuits. Flat agricultural fields that surround the test site cause a minimal amount of interference with the wind flow. The site, because of its location beside the canal, was affected by a high water table and salinity problems due to canal seepage. A subsurface drainage system was therefore designed and installed in order to dewater the area plus provide a practical demonstration of actual field conditions in which the wind and solar pumps would work.

2.2 Site Layout

Four wind turbines and seven photovoltaic water pumping systems were tested during the 1990 test season. A fifth wind turbine was under construction and not yet available for testing. The location of these is shown in Figure 2.1. Tables 2.1 and 2.2 provide summary information on

the pumping systems tested. More detailed descriptions are presented with the performance results later in this report.

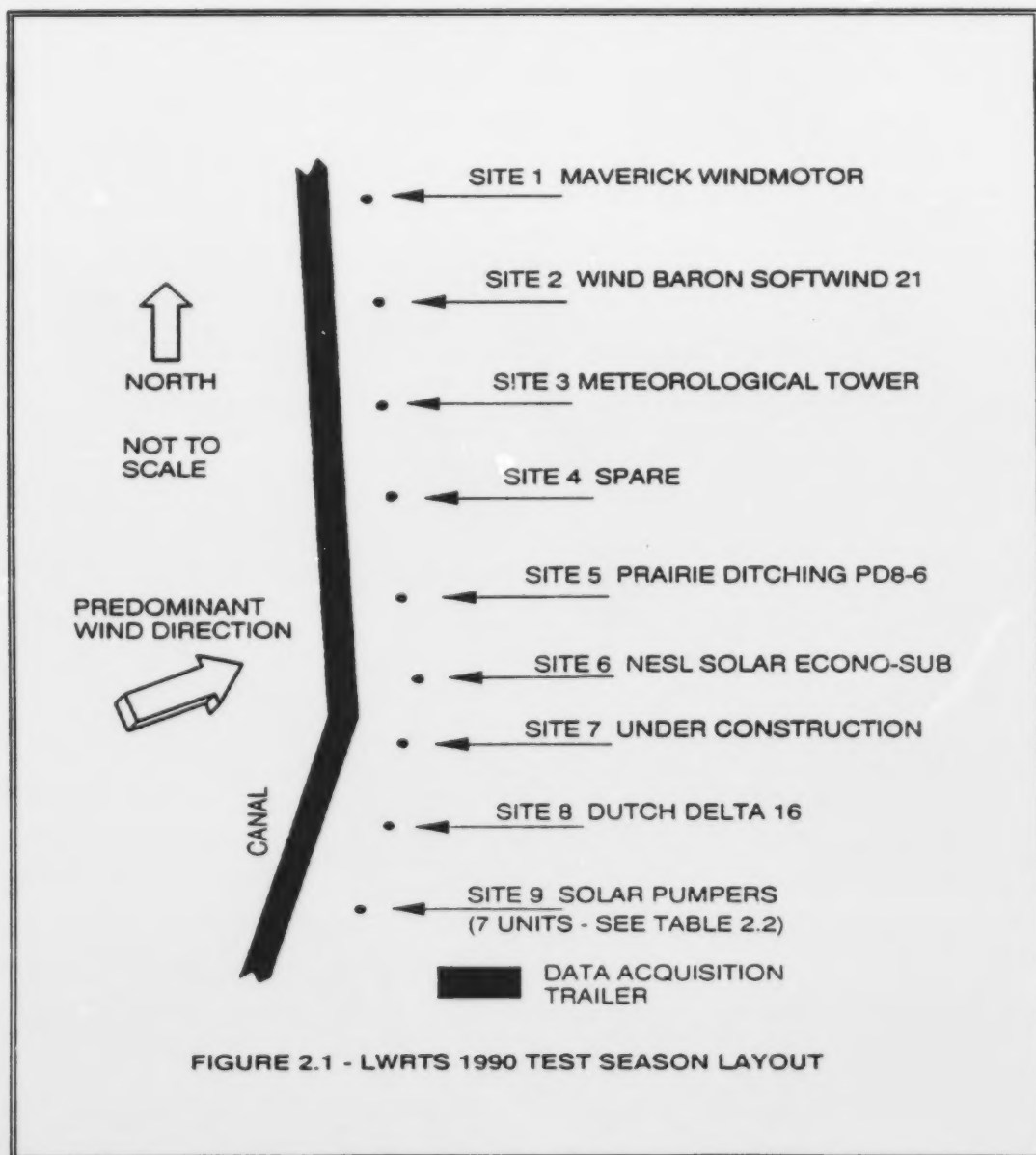


TABLE 2.1 - WIND PUMPING SYSTEMS TESTED (1990)

Model	Description	Supplier
Maverick Windmotor	3-blade rotor, cable driven progressing cavity pump	Maverick Wind Energy, Pincher Creek, Alberta (403) 627-3630
Softwind 21	Multiblade rotor, piston pump driven with a counter balance system	Wind Baron Corp., Flagstaff, Arizona, USA (602) 526-6400
Prairie #PD6-6	Multiblade rotor, air lift pump with a direct drive air compressor	Prairie Ditching, Lethbridge, Alberta (403) 327-8280
Delta 16	Multiblade rotor, piston pump driven with a counter balance system	Dutch Industries, Regina, Saskatchewan (306) 949-9522

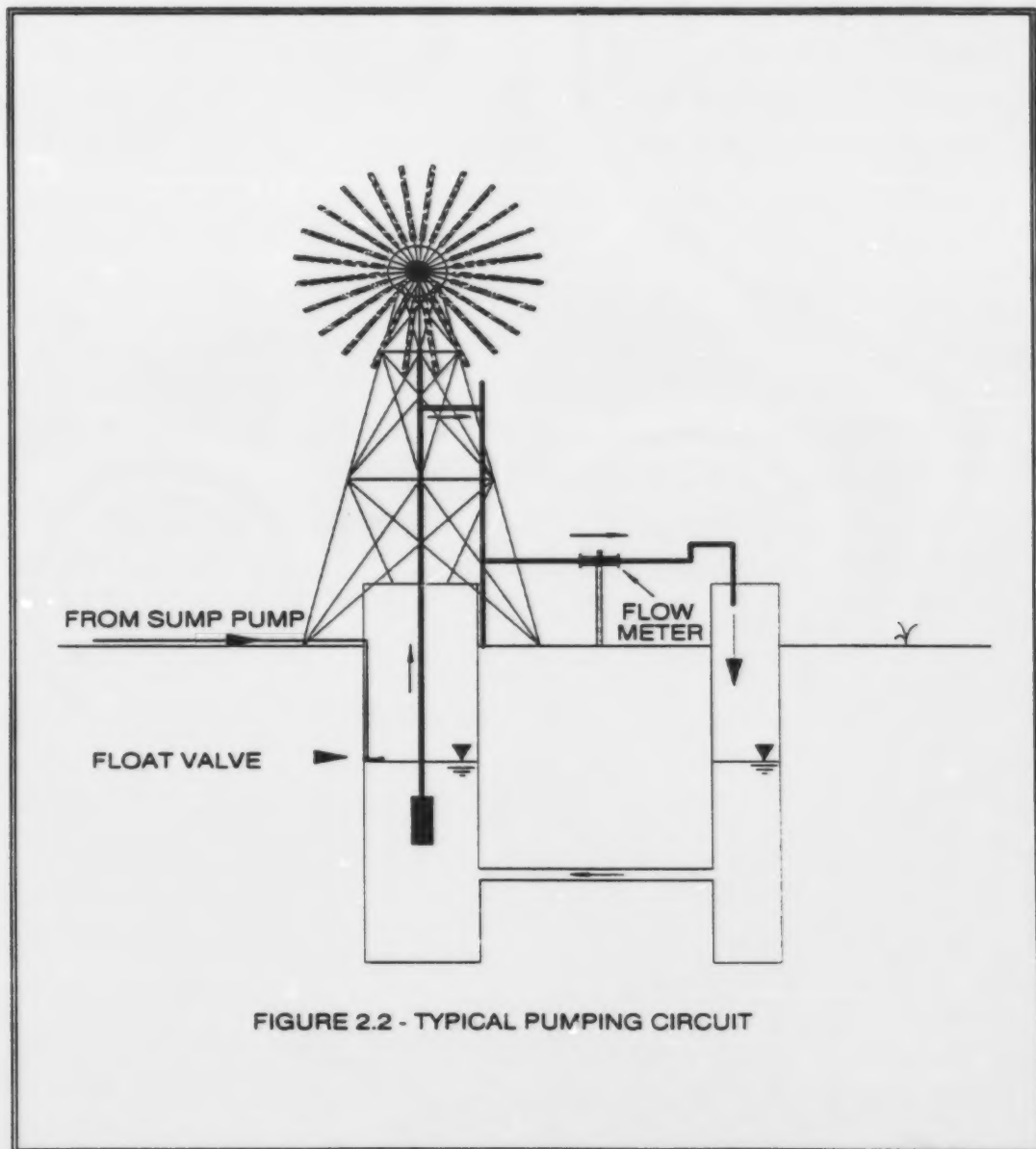
2.3 Instrumentation and Monitoring Equipment

To measure the pumping performance of the systems, closed-loop double sump systems were installed. A schematic of a typical pumping circuit is shown in Figure 2.2. The unit being tested pumps water from one sump, up a predetermined height and then into a vented standpipe. The piping used in this portion of the test circuit is sized to be consistent with actual field applications while presenting negligible dynamic head to the pump. The vented standpipe is used to separate air from the pumped water and to dampen the pulsating flows before draining through a flow-metered pipe into the second sump. Each of the turbine-type flow meters is equipped with a flow rate register for local readout as well as a pickup for remote sensing. To ensure valid flow readings, the metered pipe is sloped to maintain submergence of the flow meter and is sized to

TABLE 2.2 - SOLAR PUMPING SYSTEMS TESTED (1990)

Model	Description	Supplier
NESL Solar Econo-Sub	2 fixed Selectric photo-voltaic panels driving a 2 valve diaphragm pump	Nor'wester Energy Systems, Calgary, Alberta (403) 249-3337
CAP WARDUN	4 fixed ARCO photo-voltaic panels driving a progressing cavity pump	Canadian Agtechnology Partners, Olds, Alberta (403) 556-8779
CAP 2 Panel	2 tracking ARCO photo-voltaic panels driving a 2 valve diaphragm pump	Canadian Agtechnology Partners, Olds, Alberta (403) 556-8779
CAP 3 Panel	3 fixed ARCO photo-voltaic panels driving a 4 valve diaphragm pump	Canadian Agtechnology Partners, Olds, Alberta (403) 556-8779
CAP 4A Panel	4 tracking ARCO photo-voltaic panels driving a submersed centrifugal pump	Canadian Agtechnology Partners, Olds, Alberta (403) 556-8779
CAP 4B Panel	4 fixed ARCO photo-voltaic panels driving a surface-mount centrifugal pump	Canadian Agtechnology Partners, Olds, Alberta (403) 556-8779
CAP 8 Panel	8 ARCO photovoltaic panels driving a surface-mount centrifugal pump	Canadian Agtechnology Partners, Olds, Alberta (403) 556-8779

decrease the turbulence in the pumped water before measurement. The design also ensures that the dynamic head developed in this section will not raise the water level in the standpipe to a point where it would



contribute to the pumping head of the wind turbine. The water exiting the metered pipe provides potential users with visual evidence of the wind or solar pumper's capabilities. The loop is completed when the pumped water returns to the first sump through a connecting pipe located near the base of the two sumps.

Atmospheric monitoring for the wind turbines is performed by a centrally located meteorological tower. A Climatronic weather monitoring package is installed on the 16 metre tower and includes:

- 1) Four horizontal wind speed sensors mounted at 7.5, 10.0, 12.8 and 16.5 metres. The locations of the sensors were chosen such that the hub height of any wind turbine tested was within one metre of the height of a wind speed sensor.
- 2) One wind direction sensor mounted at 10.0 metres. This sensor is used to determine the possible existence of wind shading for the various wind turbines and anemometers.
- 3) One ambient temperature sensor mounted at 10.0 metres and one atmospheric pressure sensor mounted at 2.0 metres. These sensors are used to determine the atmospheric air density.
- 4) Local displays of the wind speed and direction at the 10.0 metre level for demonstration purposes.
- 5) Signal conditioners such that all sensor outputs can be transmitted to the data acquisition system in a consistent manner.

The incident solar radiation on the solar pumping systems is monitored by Kipp and Zonen pyranometers. The pyranometers are mounted on the framework of the photovoltaic panels.

There are many parameters which can be measured to evaluate the performance of solar and wind turbine pumping systems. It was decided

that the performance variables of most interest to users and manufacturers are: the volume flow rate as a function of wind speed and solar energy; the variation of flow with pumping head and the predicted flow volumes in a given solar and wind regime. Infrared photo pickups are also installed on wind systems to monitor their rotor speed or pump cycle speed. The solar systems have voltage and current sensors to monitor the power which is transferred to the pump from the photovoltaic panels.

The monitoring system on the site consists of a SAFE 8000 data acquisition unit and an IBM PC/XT. The SAFE 8000, programmed in an extended BASIC, samples all atmospheric sensors each second and calculates the one and ten minute average and standard deviation of these values. In addition, the one second peak wind gust at the 12.8 metre level is also determined on the theory that turbine failure will more likely result from instantaneous high wind gusts than from sustained high average winds. The pulse inputs from the flow meters and photo pickups are totalled at the end of each one and ten minute interval coinciding with the atmospheric measurements. At the end of the ten minute interval, the minimum one minute value over the ten minutes is also determined. This value indicates whether the pumping system began or stopped pumping during that ten minute interval. The results of these calculations are then transmitted to the IBM PC/XT. Both systems are housed in an environmentally controlled trailer located at the south end of the test site. The flow of data through the SAFE 8000 and the IBM PC/XT is illustrated in Figure 2.3. The IBM uses a UNIX based operating system such that it can operate in a multiuser/multitasking environment. A series of scheduled programs, written in C language, is used to facilitate the data collection, processing and transmission. The on-site processing includes producing hourly averages of each sensor input and automatically producing daily summary reports of these values. The ten minute average data is stored

on the hard disk (providing thirty days of backup storage), and is regularly retrieved by a remote PC for archiving and analysis. A menu system is provided to on-site and remote users (connected via modem) enabling them to perform a variety of functions. These include manual initiation of the previously discussed automated procedures for any data interval. The user may also obtain, in a similar fashion, data from any of the machines being tested for direct use with a spreadsheet/graphics package such as Lotus 1-2-3. Finally, the menu system allows the user to monitor, in real time, the operation of the site using the one minute data. The operating system is also configured such that password protection prevents unauthorized personnel from modifying the IBM or SAFE software. Because of the UNIX based operating system, all of these tasks can be performed without interrupting the data monitoring process.

3.0 ANALYSIS PROCEDURES

3.1 Reliability

One of the most important factors in evaluating a pumping system is its reliability. Therefore, the test site maintains operating logs of each machine. These logs include their installation date and down times due to machine repair. The logs are used to calculate the number of weeks the machines were tested and the fraction of time during this test period the machines were available for operation (regardless of wind or cloud conditions). This data will be discussed along with the presentation of the performance curves.

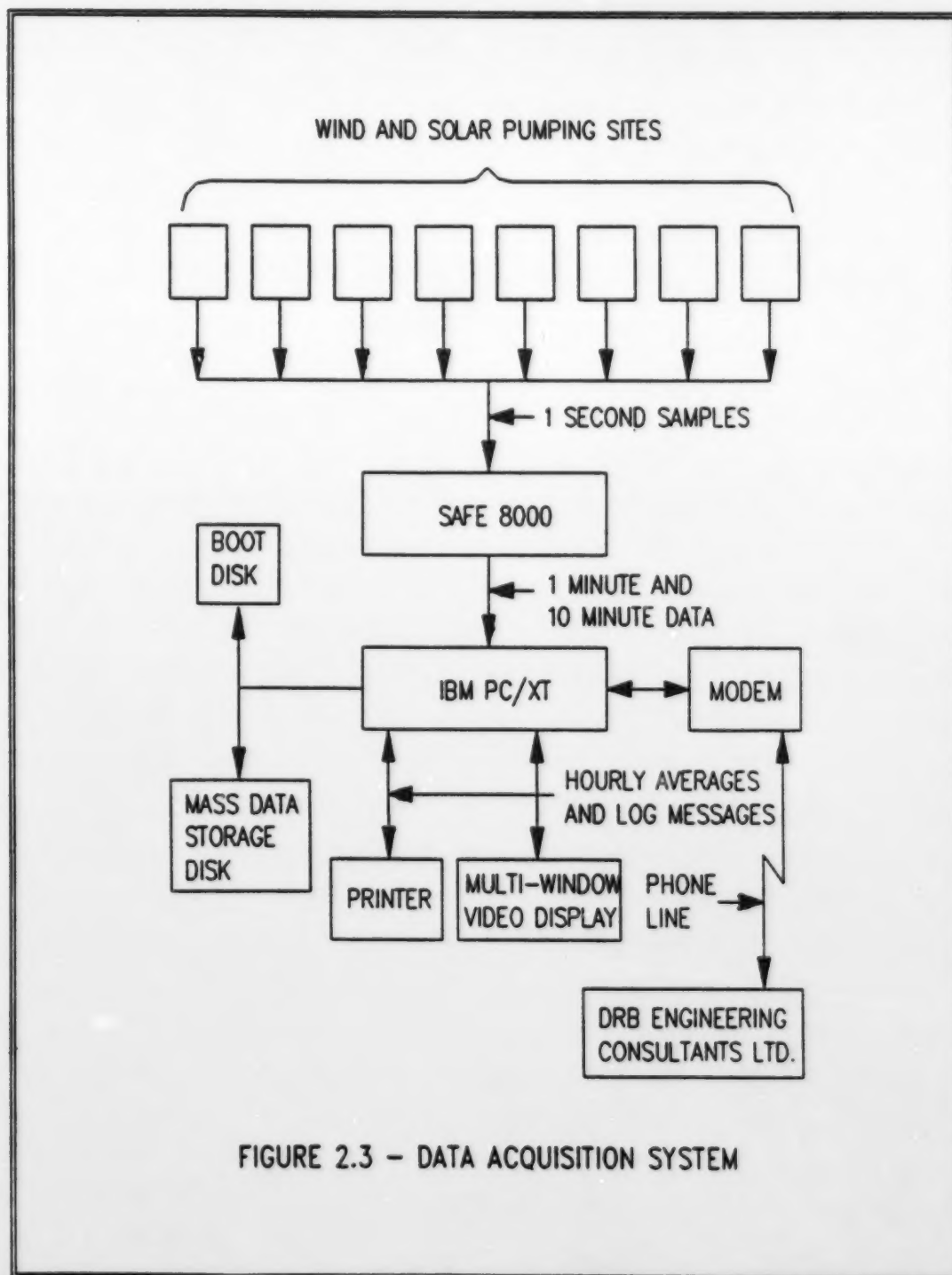


FIGURE 2.3 - DATA ACQUISITION SYSTEM

3.2 Wind Performance Curves

The monitoring and analysis procedures at the test site closely follow the Canadian Standards Association (CSA) Standard F417-M91 "Wind Energy Conversion Systems (WECS)-Performance". The monitoring method of sampling once per second and averaging over a ten minute interval agrees with the CSA standard. The only exception to the monitoring standard is that the test site does not have a separate anemometer for each wind turbine being tested. Not only would this have been a costly modification, but because of the smooth terrain characteristics of the site it was deemed unnecessary.

The collected data was first divided into separate files for each machine. These files were then filtered for invalid data sets caused by machine or monitoring failures. The wind turbine files were filtered for data sets in which the anemometers or the machine could have been shaded by surrounding turbines. In the case of the Dutch Delta 16 the data was also filtered for periods when the wind may have been shaded by a section of trees located across the canal and south of the test site. To correctly identify which records required elimination due to wind shading, a study was performed on the wind angle variation which occurs over 10 minute intervals at the test site. The results showed that the median standard deviation was 15 degrees, which meant there was a 5% chance that the wind direction would deviate more than 30 degrees from the mean (2 standard deviations) for a period of one second in the ten minute interval (assuming a normal distribution). The percentage chance would quickly approach zero as the time interval for wind directions outside the 30 degree range was increased. Hence, any data in which the mean wind direction was within 30 degrees of an obstruction was

eliminated. This differs from the CSA standard which requires the mean wind direction to be 45 degrees away from an obstruction.

After the above two filtering methods were applied to the data files, the data sets were divided into wind speed bins. For wind speeds less than 8 m/s, the width of each wind speed bin was 0.5 m/s; for winds greater than 8 m/s, the bin width was 1.0 m/s. This increased interval still agrees with the CSA standard and was applied due to the decreased amount of data recorded above 8 m/s. The mean and standard deviation of each recorded parameter was then calculated for each wind speed bin. The results were then used for the final filtering process. Chauvenet's criterion (Holman, 1978) allows the elimination of spurious data with unknown origins which is greater than approximately two standard deviations away from the mean within each wind speed bin. This criterion was applied as per the CSA standard to the measured flow rates and, if monitored, the rotor speeds. The averages and standard deviations for all parameters in each wind speed bin were then recalculated.

A final test specified by the CSA standard to determine the statistical validity of the data was applied before graphing the results. This final test checks to see if the data meets specified minimum data base requirements (MDBR) and is defined as follows:

- 1) For wind speed bins in which the parameter to be graphed (flow rate or rotor speed) is less than 25% of the maximum or rated value, then the bin shall not meet the MDBR until at least forty 10 minute averages (samples) are obtained. This controls the data such that the true mean of the bin is contained within a confidence interval of 1 standard deviation of the sample mean with a probability of 0.99.
- 2) For wind speed bins less than 15 m/s, the bin does not satisfy the MDBR until; (a) there is at least ten samples in the bin, (b)

there is a probability of 0.99 that the true mean of the bin is within 10% of the sample mean. The method for determining this value is presented in detail in the CSA standard.

- 3) For wind speed bins greater than 15 m/s, the bin does not satisfy the MDBR until; (a) there is at least ten samples in the bin, (b) there is a probability of 0.99 that the true mean of the bin is within 20% of the sample mean. This calculation is a slight variation of the above.

The results of the MDBR test, along with the average and standard deviations of each parameter within each bin are tabulated and presented with the performance results. Smooth curves of the data are generated by fitting fifth order polynomial equations to the tabulated values. The coefficients of the resulting equations are then used for subsequent volume yield calculations.

3.3 Monthly Pumping Estimates

The final calculation made from the performance curves is the potential monthly pumping estimates. These estimates are based on the pumping system being available for operation whenever the wind speed exceeds the cut-in speed of the system. They are also based on wind regimes which display Rayleigh characteristics. That is, the frequency of time winds are found within any wind speed interval (e.g. from v_x to v_y) may be calculated by incorporating the mean wind speed ($\bar{v}$) in the following equation:

$$F(v_x \leq v \leq v_y) = \exp\left[-\left(\frac{\pi}{4}\right)\left(\frac{v_x}{\bar{v}}\right)^2\right] - \exp\left[-\left(\frac{\pi}{4}\right)\left(\frac{v_y}{\bar{v}}\right)^2\right]$$

To calculate the wind turbine's monthly pumping potential, the flow rate values determined by the fifth order polynomial fit to the binned data is integrated with the fraction of time (F) that the wind would blow within each wind speed interval. The sum of these values is equal to the average pumping rate of the wind turbine. The potential volume the system could pump is then determined by multiplying this average with the time period in question (this study uses 30 day months). Repeating this calculation for a variety of mean wind speeds allows the graphing of the monthly pumping potential against mean wind speed.

3.4 Solar Performance Curves

Performance curves for the solar pumping systems were determined by the same algorithm as the wind pump systems. The only specific changes were:

- 1) the solar files were filtered for invalid data sets caused by the pyranometers and/or photovoltaic panels being shaded by a nearby utility pole.
- 2) the performance data was divided into solar radiation intensity bins. For solar radiation values less than 800 W/m², the width of each bin was 50 W/m²; for solar radiation values greater than 800 W/m², the width of each bin was 100 W/m².

- 3) no monthly pumping yields were determined because of the lack of a standard method of describing the distribution of solar radiation intensity values.

4.0 PRESENTATION AND DISCUSSION OF RESULTS

The following section presents and discusses the performance characteristics of the pumping systems tested. The machines are discussed in the order of their placement on the site (Figure 2.1) and are presented as "pull-out" sections. The raw data from which the performance tables and graphs were derived are available from the test site on request.

The wind turbine summary tables indicate the air density observed in each wind speed bin. In accordance with the CSA performance testing standard, the performance data have not been adjusted to standard atmospheric conditions. On some of the wind turbine summary tables the turbulence intensity is also indicated. The turbulence intensity is a measure of the variability of the wind speed over each ten minute period and is expressed as the ratio of the first standard deviation of wind speed to the mean wind speed. An analysis for the entire period showed that the average turbulence intensity for winds at ten metres elevation was fourteen percent. This is a relatively low value which provides another indication that the data collected by the meteorological tower accurately represents the winds experienced by the entire site.

The summary tables for the solar pumping systems indicate the average wind speed and ambient air temperature at which the data was recorded. These two parameters will affect the surface temperature that the photovoltaic panels attain during the test. This is important as the performance of the

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photovoltaic panels are affected by their surface temperature. However, as with the air density effect on wind turbines, no performance correction has been made for the panel temperature effect on the solar systems.

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LETHBRIDGE WIND RESEARCH TEST SITE 1990 TEST RESULTS OF THE MAVERICK WINDMOTOR

The Maverick Windmotor has been tested under several configurations since 1987. The configuration tested in 1990 was very similar to its final configuration in 1988 (it was not tested in 1989). This unit is a downwind, three-bladed machine with a rotor diameter of 2.44 m. It is manufactured in Pincher Creek, Alberta. The rotor is unique because the blades do not radiate out from the central hub, but are mounted perpendicular to the rotor supports at the extreme edge of the rotor circumference. The force of the wind on the blades combined with the rotational speed of the rotor regulates the pitch of the blades. This results in the unit being self regulating and removes the requirement for a cut-out wind speed. The single stage helical progressive cavity pump is driven directly by the rotor via a flexible cable. The pump is designed to produce 13.6 litres per 100 RPM of the rotor.

The performance curves shown on the specification sheet indicates that the system requires a rotor speed of 25 RPM before the pump begins to deliver water. This results in a cut-in wind speed of 2.5 m/s. At 10 m/s the pump delivers 20 litres per 100 RPM of the rotor (40 l/min ÷ 200 rotations/min).

This season marks the first season that sufficient data was collected to estimate its monthly pumping potential. The pump yield curve shows that this turbine can pump 600 cubic metres of water per month at locations with a 5 m/s average monthly wind speed. Using a typical requirement for range cattle of 54 litres per cow per day, this would be sufficient to supply water for 370 cows. This assumes no losses (evaporation, wastage, etc.) and sufficient storage to handle all water pumped.

The manufacturer has begun a major research and development program to continue to improve the rotor and pump designs. The latest modifications to this design resulted in a fault free year of testing. Additional testing will enable a true assessment of the machines reliability.

METHOD OF BIN RESULTS FOR: MAVERICK WINDMOTOR
PUMPING AGAINST A 5.5 METRE HEAD

BIN NO.	BIN INTERVAL	NUMBER OF REDUCED DATA SETS	--- BIN SAMPLE AVERAGE ---			STANDARD DEVIATION			MEET CSA MDR REQUIREMENTS		
			AIR DENSITY KG/M ³	WIND SPEED M/S	ROTOR SPEED RPM	FLOW RATE L/MIN	WIND SPEED M/S	ROTOR SPEED RPM	FLOW RATE L/MIN	ROTOR FLOW RATE	MEET CSA MDR REQUIREMENTS
1	1.5 TO 2.0	129	1.079	1.82	4.9	0.06	0.12	3.8	0.23	Y	Y
2	2.0 TO 2.5	449	1.086	2.29	9.3	0.13	0.14	6.7	0.34	Y	Y
3	2.5 TO 3.0	989	1.089	2.76	18.4	0.51	0.14	10.8	0.91	Y	Y
4	3.0 TO 3.5	1247	1.090	3.24	31.2	1.62	0.14	13.2	1.81	Y	Y
5	3.5 TO 4.0	872	1.088	3.73	50.5	4.81	0.14	14.5	2.91	Y	Y
6	4.0 TO 4.5	672	1.086	4.24	70.3	9.09	0.14	12.6	2.88	Y	Y
7	4.5 TO 5.0	450	1.084	4.73	86.1	12.74	0.14	11.1	2.65	Y	Y
8	5.0 TO 5.5	410	1.082	5.23	101.9	16.37	0.15	10.6	2.50	Y	Y
9	5.5 TO 6.0	284	1.079	5.73	116.0	19.67	0.14	10.2	2.52	Y	Y
10	6.0 TO 6.5	266	1.076	6.25	128.2	22.56	0.14	8.3	2.14	Y	Y
11	6.5 TO 7.0	216	1.072	6.73	138.7	25.06	0.14	8.6	2.16	Y	Y
12	7.0 TO 7.5	190	1.073	7.23	149.9	27.78	0.14	8.4	2.15	Y	Y
13	7.5 TO 8.0	135	1.072	7.72	160.2	30.37	0.15	9.3	2.51	Y	Y
14	8.0 TO 9.0	245	1.071	8.47	174.4	33.83	0.28	9.2	2.42	Y	Y
15	9.0 TO 10.0	174	1.074	9.43	189.4	37.06	0.29	8.2	1.99	Y	Y
16	10.0 TO 11.0	60	1.077	10.40	203.7	40.41	0.27	6.6	1.66	Y	Y
17	11.0 TO 12.0	24	1.075	11.40	216.9	43.32	0.32	9.0	2.12	Y	Y
18	12.0 TO 13.0	18	1.073	12.53	233.5	47.17	0.27	8.9	2.02	Y	Y
19	13.0 TO 14.0	21	1.072	13.54	242.3	49.09	0.25	8.0	1.66	Y	Y
20	14.0 TO 15.0	4	1.072	14.52	250.3	51.65	0.27	5.9	1.44	M	M
21	15.0 TO 16.0	8	1.071	15.39	266.0	54.50	0.28	6.1	1.32	M	M
22	16.0 TO 17.0	-	-	-	-	-	-	-	-	M	M
23	17.0 TO 18.0	-	-	-	-	-	-	-	-	M	M

TOTAL NUMBER OF
REDUCED DATA SETS: 6863
AVERAGE TEMPERATURE
DURING THE TEST: 292.5 DEGREES KELVIN
AVERAGE PRESSURE
DURING THE TEST: 91.00 KPA

LETHBRIDGE WIND RESEARCH TEST SITE
SPECIFICATIONS and PERFORMANCE SUMMARY
1990 TEST SEASON

WINDPUMP NAME: Maverick Windmotor

SUPPLIER: Maverick Wind Energy Ltd.
ADDRESS: P.O. Box 2707
Pincher Creek, Alberta, Canada
T0K 1W0
TELEPHONE: (403) 627-3630
(403) 627-3091

PHYSICAL DESCRIPTION:

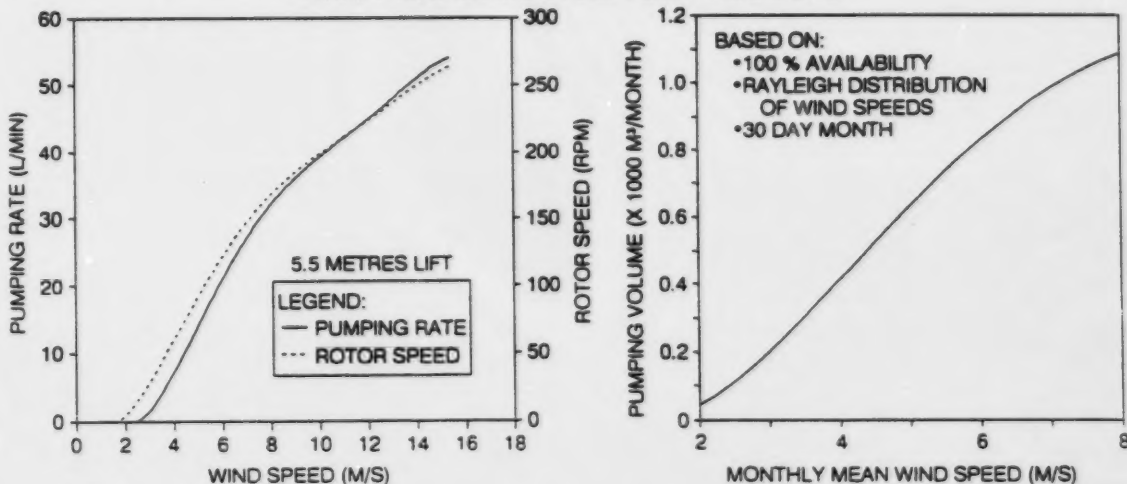
Turbine Type: downwind
Axis: horizontal
Rotor Diameter: 2.44 m
Swept Area: 4.68 m²
Number of Blades: 3
Blade Design: proprietary
Blade Material: extruded aluminum
Hub Height: 7.62 m
Transmission: direct drive
Gear Ratio: 1 : 1
Pump Type: helical progressing cavity
Pump Size: 51 mm diameter
Pumping System Description:
direct cable drive from
rotor to pump

PERFORMANCE:

Testing Period: 97 days
Period Operational: 97 days
Percent Availability: 100 %

INSTALLED: June 22, 1990

1990 PERFORMANCE TEST RESULTS



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**LETHBRIDGE WIND RESEARCH TEST SITE
1990 TEST RESULTS OF THE
WIND BARON SOFTWIND 21**

The Wind Baron is very similar in looks to the standard American water pumper. Its rotor is 6.4 metres in diameter and consists of 18 blades. It utilizes a large (300 mm diameter X 518 mm stroke) positive displacement pump. The torque required to initiate operation of the windmill has been reduced substantially by the use of a counter-balance mechanism. The mechanism requires the turbine to lift a weight (equal to half the weight of the water and all the weight of the sucker rod and pump) when the pump is on the down stroke. During the pump up stroke, this counter-balance then offsets half the weight of the water and all the weight of the sucker rod and pump. Further requirements to start-up torque are achieved by a mechanical gear box which requires 3.25 rotor rotations per pump stroke.

The windmill installed was a prototype and was under its first year of test. As is expected in the first year of testing, several teething problems were encountered. The problems were also typical of those found with large volume, low lift wind pumping applications. They all were caused by the pump linkages and the windmill furling mechanisms. Because of these problems only 29 days of data were collected.

The data collected shows the machine has an excellent cut-in wind speed of 1.75 m/s. This is in exact agreement with that published by the manufacturer. It is capable of pumping 490 l/min at 12 m/s, suitable for many small scale irrigation applications. It is one of the largest windmills tested at the Lethbridge Wind Research Test Site.

The manufacturer will continue development and testing of his mill during the 1991 test season.

METHOD OF BIN RESULTS FOR: WIND BARON SOFTWIND 21
PUMPING AGAINST A 5.5 METRE HEAD

BIN NO.	BIN INTERVAL	NUMBER OF REDUCED DATA SETS	--- BIN SAMPLE ---			AVERAGE			STANDARD DEVIATION			MEET CSA MDR		
			AIR DENSITY KG/H ³	WIND SPEED H/S	WIND SPEED H/S	RPM	FLOW RATE L/MIN	WIND SPEED H/S	RPM	FLOW RATE L/MIN	WIND SPEED H/S	ROTOR FLOW RATE L/MIN	ROTOR FLOW RATE L/MIN	ROTOR FLOW RATE L/MIN
1	1.5 TO 2.0	21	1.118	1.88	2.30	3.7	6.45	0.09	0.9	5.57	N	5.57	N	N
2	2.0 TO 2.5	98	1.108	2.30	2.74	6.7	16.64	0.14	1.7	12.33	Y	12.33	Y	Y
3	2.5 TO 3.0	115	1.107	2.74	3.23	10.9	37.86	0.14	2.4	18.39	Y	18.39	Y	Y
4	3.0 TO 3.5	98	1.099	3.23	3.71	15.3	73.14	0.13	2.6	22.64	Y	22.64	Y	Y
5	3.5 TO 4.0	67	1.105	3.71	4.22	19.0	103.32	0.14	2.6	21.64	N	21.64	N	Y
6	4.0 TO 4.5	46	1.097	4.22	4.75	22.8	139.63	0.14	1.6	18.01	N	18.01	N	Y
7	4.5 TO 5.0	38	1.098	4.75	5.26	25.6	175.74	0.13	1.7	17.61	N	17.61	N	Y
8	5.0 TO 5.5	37	1.090	5.26	5.76	27.8	206.28	0.14	1.5	16.89	N	16.89	N	Y
9	5.5 TO 6.0	18	1.097	5.76	6.25	30.9	238.35	0.15	1.4	16.79	N	16.79	N	Y
10	6.0 TO 6.5	19	1.096	6.25	6.72	33.2	274.00	0.13	1.6	23.98	N	23.98	N	Y
11	6.5 TO 7.0	6	1.090	6.72	7.17	36.9	295.60	0.13	2.0	21.25	N	21.25	N	Y
12	7.0 TO 7.5	6	1.092	7.17	7.76	38.3	330.56	0.13	1.4	25.44	N	25.44	N	Y
13	7.5 TO 8.0	4	1.090	7.76	8.60	43.0	342.56	0.11	1.0	11.68	N	11.68	N	Y
14	8.0 TO 9.0	4	1.086	8.60	9.65	46.5	398.70	0.22	1.9	23.61	N	23.61	N	Y
15	9.0 TO 10.0	8	1.085	9.65	10.44	48.9	433.66	0.25	1.7	25.45	N	25.45	N	Y
16	10.0 TO 11.0	15	1.089	10.44	11.28	50.1	462.98	0.32	1.7	18.47	N	18.47	N	Y
17	11.0 TO 12.0	10	1.079	11.28	12.13	50.1	476.57	0.16	2.2	20.80	N	20.80	N	Y
18	12.0 TO 13.0	5	1.078	12.13	13.40	49.0	487.11	0.08	1.2	15.06	N	15.06	N	Y
19	13.0 TO 14.0	5	1.079	13.40	-	-	457.51	0.36	4.1	44.11	N	44.11	N	Y
20	14.0 TO 15.0	-	-	-	-	-	-	-	-	-	N	-	N	Y
21	15.0 TO 16.0	-	-	-	-	-	-	-	-	-	N	-	N	Y
22	16.0 TO 17.0	-	-	-	-	-	-	-	-	-	N	-	N	Y
23	17.0 TO 18.0	-	-	-	-	-	-	-	-	-	N	-	N	Y

TOTAL NUMBER OF REDUCED DATA SETS: 623
AVERAGE TEMPERATURE DURING THE TEST: 288.6 DEGREES KELVIN
AVERAGE PRESSURE DURING THE TEST: 91.15 KPA

LETHBRIDGE WIND RESEARCH TEST SITE
SPECIFICATIONS and PERFORMANCE SUMMARY
1990 TEST SEASON

WINDPUMP NAME: **Softwind 21**

SUPPLIER: Wind Baron Corp.
ADDRESS: 3920 East Huntington Drive
Flagstaff, Arizona, U.S.A.
86004
TELEPHONE: (602) 526-6400

PHYSICAL DESCRIPTION:

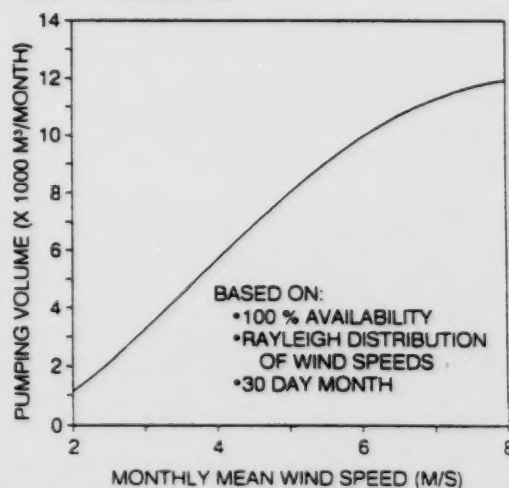
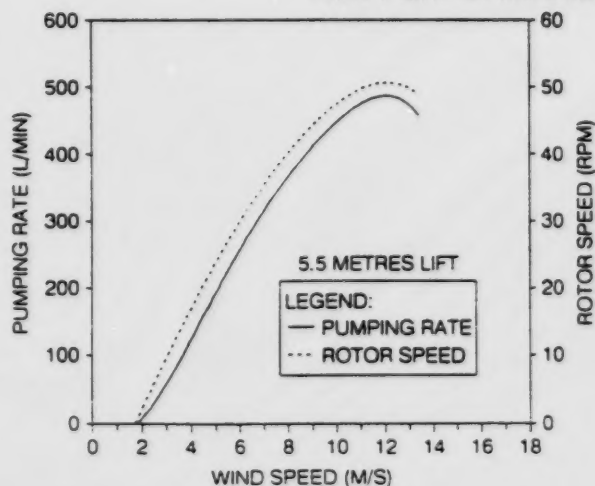
Turbine Type: upwind
Axis: horizontal
Rotor Diameter: 6.4 m
Swept Area: 32.17 m²
Number of Blades: 18
Blade Design: high torque sails
Blade Material: galvanized steel
Hub Height: 12.2 m
Transmission: mechanical gearing
Gear Ratio: 3.25:1
Pump Type: reciprocating piston
Pump Size: 305 mm diameter
Stroke: 518 mm
Pumping System Description:
reciprocating rod connected to
positive displacement pump

PERFORMANCE:

Testing Period: 108 days
Period Operational: 29 days
Percent Availability: 26.9 %

INSTALLED: May 30, 1990

1990 PERFORMANCE TEST RESULTS



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**LETHBRIDGE WIND RESEARCH TEST SITE
1990 TEST RESULTS OF THE
PRAIRIE #PD8-6**

The Prairie #PD8-6 represents the result of seven years of development by Prairie Ditching of Lethbridge, Alberta. Previous to this entirely custom designed unit, the manufacturer had tested stock and modified versions of the Bowjon Rancher. The results of the Bowjon tests can be found in the summary reports produced by the Lethbridge Wind Research Test Site since 1983. The Prairie rotor consists of 6 polyethylene blades which directly drive an air compressor. The air compressor supplies compressed air which is injected into an air lift pump. The air lift pump consists of a perforated foot piece set in the center of an open-ended cylinder. The air is discharged through the foot piece, thus producing an air and water mixture. The mixture rises because it possesses a lower density than the water surrounding the pump. The advantage of an air lift pump is that it will not be harmed if it experiences dry well or freezing conditions.

The performance and monthly pumping potential of the Prairie unit is shown on its specification sheet. It results show that if the monthly average wind speed at a potential installation is 5 m/s (at hub height) then the pumping potential for the Prairie would be 400 cubic metres for the month. This is on the condition that it is available for operation 100% of the time, and the unit is pumping against a 5.5 metre head.

This was the second year of testing for the Prairie #PD8-6, therefore an indication of its reliability is beginning to show. It was operational for 96.5% of the time over its first two years of testing, which is relatively high for a machine at this stage of its development. The only down time was the result of one of the blades bending backwards and stalling the machine during the first year of testing. In the second year the manufacturer added support struts to alleviate this problem. One failure of the support struts occurred in the second year, but this did not interfere with the operation of the mill.

METHOD OF BIN RESULTS FOR: PRAIRIE PD8-6
PUMPING AGAINST A 5.5 METRE HEAD

BIN NO.	BIN INTERVAL F/S	NUMBER OF REDUCED DATA SETS N	AIR DENSITY KG/M ³	WIND SPEED M/S	FLOW RATE L/MIN	STANDARD DEVIATION WIND SPEED M/S	FLOW RATE L/MIN	MEET CSA MDRR REQUIREMENTS FOR FLOW RATE
1	1.5 TO 2.0	15	1.077	1.84	0.25	0.13	0.35	N
2	2.0 TO 2.5	119	1.082	2.33	0.30	0.13	0.33	Y
3	2.5 TO 3.0	503	1.087	2.78	0.69	0.14	0.70	Y
4	3.0 TO 3.5	752	1.087	3.25	1.87	0.14	1.46	Y
5	3.5 TO 4.0	507	1.085	3.73	4.11	0.15	2.17	Y
6	4.0 TO 4.5	394	1.083	4.23	6.89	0.13	2.30	Y
7	4.5 TO 5.0	264	1.083	4.73	9.64	0.14	2.29	Y
8	5.0 TO 5.5	224	1.081	5.23	11.67	0.15	1.74	Y
9	5.5 TO 6.0	134	1.082	5.73	13.52	0.14	1.56	Y
10	6.0 TO 6.5	122	1.080	6.25	15.01	0.15	1.30	Y
11	6.5 TO 7.0	106	1.079	6.72	16.07	0.14	1.24	Y
12	7.0 TO 7.5	106	1.075	7.24	17.22	0.14	1.10	Y
13	7.5 TO 8.0	75	1.076	7.72	18.04	0.15	0.89	Y
14	8.0 TO 9.0	146	1.073	8.46	19.04	0.28	0.80	Y
15	9.0 TO 10.0	117	1.078	9.46	19.88	0.30	0.72	Y
16	10.0 TO 11.0	51	1.076	10.39	20.23	0.26	0.56	Y
17	11.0 TO 12.0	16	1.074	11.32	18.84	0.30	1.70	Y
18	12.0 TO 13.0	17	1.072	12.54	16.21	0.27	0.76	Y
19	13.0 TO 14.0	22	1.072	13.53	13.06	0.25	1.38	Y
20	14.0 TO 15.0	4	1.072	14.52	11.28	0.27	0.35	N
21	15.0 TO 16.0	8	1.071	15.39	10.64	0.28	0.81	N
22	16.0 TO 17.0	-	-	-	-	-	-	N
23	17.0 TO 18.0	-	-	-	-	-	-	N

TOTAL NUMBER OF REDUCED DATA SETS: 3702
AVERAGE TEMPERATURE DURING THE TEST: 292.8 DEGREES KELVIN
AVERAGE PRESSURE DURING THE TEST: 90.96 KPA

LETHBRIDGE WIND RESEARCH TEST SITE
SPECIFICATIONS and PERFORMANCE SUMMARY
1990 TEST SEASON

WINDPUMP NAME: **Prairie #PD8-6**

SUPPLIER: Prairie Ditching Ltd.
ADDRESS: 418 - 26 Street, South
Lethbridge, Alberta, Canada
T1J 3R2

TELEPHONE: (403) 327-8280

PHYSICAL DESCRIPTION:

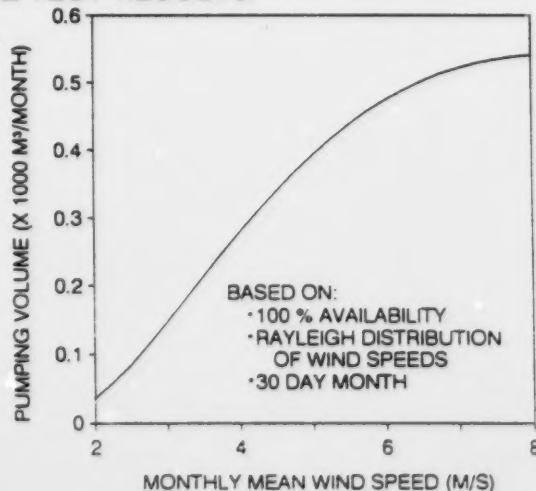
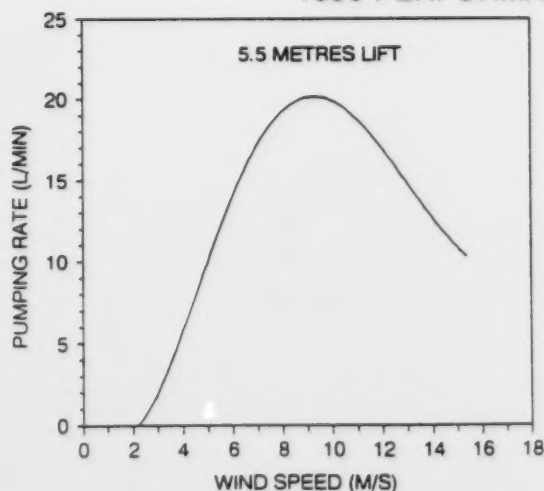
Turbine Type: upwind
Axis: horizontal
Rotor Diameter: 2.24 m
Swept Area: 3.924 m²
Number of Blades: 6
Blade Design: proprietary
Blade Material: polyethelene
Hub Height: 7.74 m
Transmission: direct drive
Pump Type: air lift
Pumping System Description:
windmill driven air compressor

PERFORMANCE:

Testing Period: 227 days
Period Operational: 219 days
Percent Availability: 96.5 %

INSTALLED: July 17, 1989

1990 PERFORMANCE TEST RESULTS



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**LETHBRIDGE WIND RESEARCH TEST SITE
1990 TEST RESULTS OF THE
NESL SOLAR ECONO-SUB**

This is the first photovoltaic pumping system to be tested by Nor'wester Energy Systems Ltd. Previously, NESL used the test site to develop their electric wind turbine water pumping system known as the Maestro. Testing of the photovoltaic system acts as the second step towards assembling a hybrid (wind/photovoltaic) system for test.

The Solar Econo-sub utilizes two Selectric 50 Watt panels wired in series. The panels are mounted on a non-tracking structure. The output of the panels drive a two valve diaphragm pump. The system distinguishes itself by having the lowest cut-in value (50 Watts/m^2) of all photovoltaic systems ever tested at the LWRTS. Because of this low cut-in value, this system would not benefit from utilizing a tracking mount. It achieves it peak output at 500 Watts/m^2 of 6 l/min. This is a relatively low peak output, but daily volume production would be assisted by the fact that it is operational for almost all day light hours. Daily volume production estimates have not been calculated for this system. It was noted however that during a typical sunny day (September 2, 1990) in Lethbridge, the system pumped 3100 litres.

The system was not installed until August 15 of 1990, allowing for only 42 days of testing. This is not sufficient time to assess the reliability of this system.

METHOD OF BIN RESULTS FOR: NESL SOLAR ECONO-SUB 2 PANEL
PUMPING AGAINST A 5.5 METRE HEAD

BIN NO.	BIN INTERVAL KW/H ²	NUMBER OF REDUCED DATA SETS N	BIN SAMPLE SOLAR RAD. KW/H ²	AVERAGE FLOW RATE L/HIN	STANDARD DEVIATION SOLAR RAD. KW/H ²	FLOW RATE L/HIN	MEET CSA HDRR REQUIREMENTS FOR FLOW RATE
1	0.00 TO 0.05	2	0.045	0.06	0.001	0.03	N
2	0.05 TO 0.10	74	0.079	0.27	0.013	0.17	Y
3	0.10 TO 0.15	113	0.125	0.77	0.014	0.28	Y
4	0.15 TO 0.20	82	0.173	1.30	0.014	0.31	Y
5	0.20 TO 0.25	81	0.224	1.96	0.015	0.30	Y
6	0.25 TO 0.30	55	0.275	2.63	0.015	0.34	Y
7	0.30 TO 0.35	45	0.324	3.25	0.014	0.35	Y
8	0.35 TO 0.40	52	0.374	3.72	0.014	0.29	Y
9	0.40 TO 0.45	65	0.425	4.41	0.015	0.37	Y
10	0.45 TO 0.50	67	0.475	5.28	0.016	0.46	Y
11	0.50 TO 0.55	54	0.526	5.87	0.014	0.11	Y
12	0.55 TO 0.60	73	0.575	5.88	0.015	0.08	Y
13	0.60 TO 0.65	79	0.625	5.88	0.015	0.09	Y
14	0.65 TO 0.70	96	0.675	5.88	0.014	0.09	Y
15	0.70 TO 0.75	104	0.726	5.88	0.014	0.09	Y
16	0.75 TO 0.80	96	0.774	5.89	0.013	0.08	Y
17	0.80 TO 0.85	112	0.824	5.88	0.014	0.08	Y
18	0.85 TO 0.90	116	0.874	5.87	0.014	0.08	Y
19	0.90 TO 0.95	140	0.927	5.88	0.015	0.08	Y
20	0.95 TO 1.00	184	0.977	5.89	0.014	0.08	Y
21	1.00 TO 1.10	271	1.028	5.89	0.018	0.07	Y
22	1.10 TO 1.20	2	1.150	6.03	0.017	0.02	N
23	1.20 TO 1.30	-	-	-	-	-	-

TOTAL NUMBER OF
REDUCED DATA SETS: 1963
AVERAGE TEMPERATURE
DURING THE TEST: 292.3 DEGREES KELVIN
AVERAGE WIND SPEED
DURING THE TEST: 4.48 M/S

LETHBRIDGE WIND RESEARCH TEST SITE
SPECIFICATIONS and PERFORMANCE SUMMARY
1990 TEST SEASON

SOLAR PUMP NAME: Solar Econo-Sub

SUPPLIER: Nor'wester Energy
Systems Ltd.

ADDRESS: Box 7, Site 32, R.R. 12
Calgary, Alberta, Canada
T3E 6W3

TELEPHONE: (403) 249-3337

PHYSICAL DESCRIPTION:

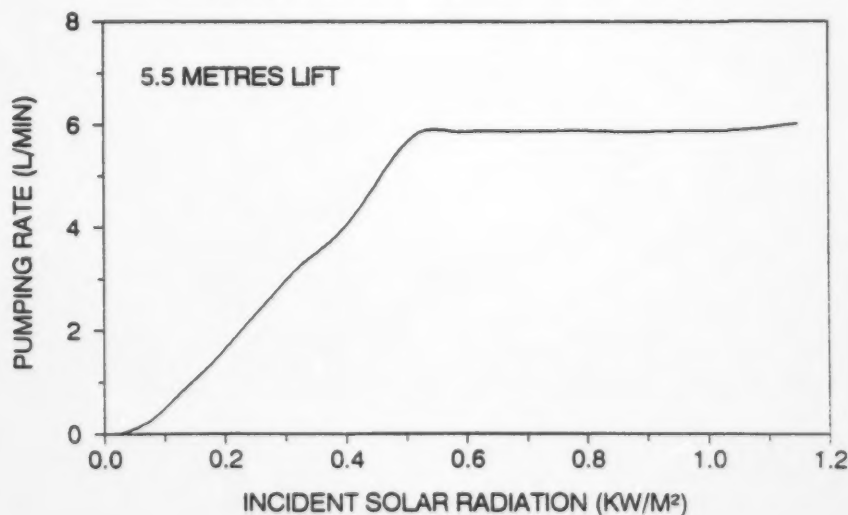
Number of Panels: 2
Panel Manufacturer: Selectric
Power Rating @ 25 C and 1000 W/m²: 50 W/panel
Configuration: series
Mount: fixed
Pump Type: positive displacement

PERFORMANCE:

Testing Period: 42 days
Period Operational: 42 days
Percent Availability: 100 %

INSTALLED: August 15, 1990

1990 PERFORMANCE TEST RESULTS



**LETHBRIDGE WIND RESEARCH TEST SITE
1990 TEST RESULTS OF THE
DUTCH DELTA 16**

The Dutch wind turbine is a new form of a direct drive type water pumping wind turbine. The unit has a rotor diameter of 4.9 m and is equipped with what has been termed as a perimeter-bladed rotor. This rotor is a special low-speed version of the delta-wing rotor developed at the University of Calgary. The rotor installed on the Dutch consists of 32 delta-wing blades attached to perimeter tubing connected via spokes to the crank shaft. The objective of this design is to achieve maximum torque at cut-in and limit the rotor speed such that it may be directly coupled to a reciprocating pump. Previous direct drive pumping systems have had problems with excessive pump-rod acceleration due to the high speed reciprocating action of the crank. To further improve its cut-in wind speed capabilities, the Delta 16 utilizes a counter-balance mechanism. The mechanism requires the turbine to lift a weight equal to half the weight of the water and sucker rod when the pump is on the down stroke. During the pump up stroke, this counter-balance then offsets half the weight of the water and sucker rod. The tower is also unique, as it allows the head, rotor and tail to be assembled near ground level prior to being slid up the inclined tower side. The entire assembly can be slid up one side of the tower by means of a hand winch.

The performance of the Dutch is shown on its specification sheet. These curves show that the wind turbine design has achieved its goal of limiting the rotor speed to under 30 RPM. In a location that has a Rayleigh distribution of winds with a mean of 5 m/s, the Dutch has the potential of pumping 5000 cubic metres per month at 5.5 metres lift.

The unit has proven to be highly reliable. It has been operation for 265 of the 286 days of testing performed in 1989 and 1990. The majority of this down time has been related to pump problems. These are presently being addressed in Dutch Industries research and development program.

LETHBRIDGE WIND RESEARCH TEST SITE
SPECIFICATIONS and PERFORMANCE SUMMARY
1990 TEST SEASON

WINDPUMP NAME: **Delta 16**

SUPPLIER: Dutch Industries Ltd.
ADDRESS: 705 - 1st Avenue
Regina, Sask., Canada
S4N 4M4
TELEPHONE: (306) 949-9522

PHYSICAL DESCRIPTION:

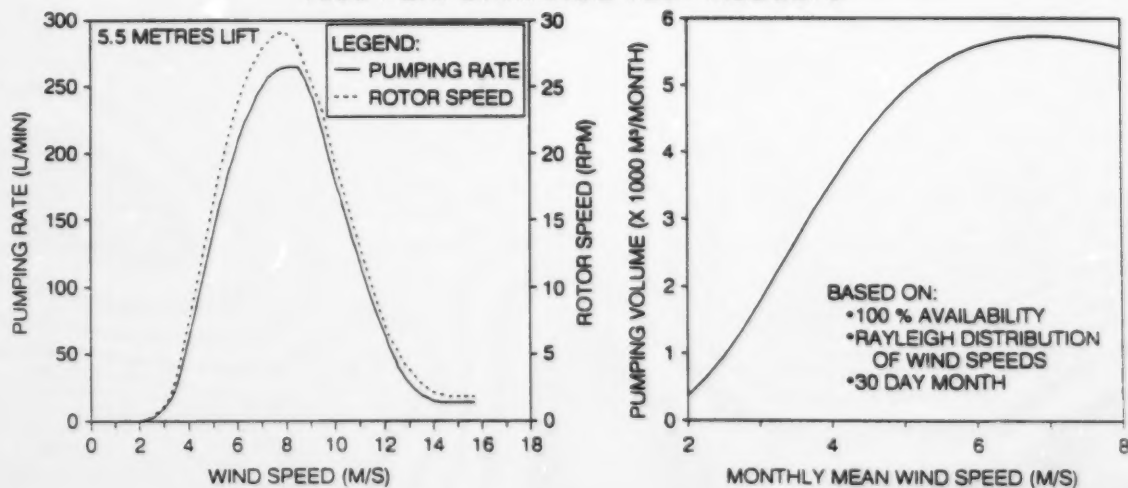
Turbine Type: upwind
Axis: horizontal
Rotor Diameter: 4.82 m
Swept Area: 7.48 m²
Number of Blades: 32
Blade Design: Delta Wing
Blade Material: mild steel (20 GA)
Hub Height: 8.25 m
Transmission: direct drive
Gear Ratio: 1:1
Pump Type: reciprocating piston
Pump Size: 264 mm diameter
Stroke: 165 mm
Pumping System Description:
reciprocating rod connected to
positive displacement pump

PERFORMANCE:

Testing Period: 286 days
Period Operational: 265 days
Percent Availability: 96.2 %

INSTALLED: May 18, 1989

1990 PERFORMANCE TEST RESULTS



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**LETHBRIDGE WIND RESEARCH TEST SITE
1988 - 1989 TEST RESULTS OF
CANADIAN AGTECHNOLOGY PARTNERS SOLAR SYSTEMS**

Canadian Agtechnology Partners tested several photovoltaic pumping systems in 1990. Most of these systems were tested only with the Deep Well Simulator. Six of the systems were also tested using conventional means. The performance results of these six systems are presented on the following pages.

Of the six systems, two were also tested in 1989. Both of these systems (CAP 2 Panel and CAP 4A Panel) achieved 100% reliability over the two years. The remaining four systems were not tested for sufficient time to assess their reliability. One of the four systems (the WARDUN system) was a joint development project which utilized a helical progressing cavity pump developed by Peter Ward & Associates Ltd. located in Vancouver, B.C. Another of the four systems was new to the CAP product line (CAP 3 Panel) and was installed for development purposes only.

The testing program has enabled the company to design and manufacture their own pumps. This was a major goal, as the company was not satisfied with the level of component matching between available pumps and photovoltaic panels.

METHOD OF BIN RESULTS FOR: CAP WARDUN 4 PANEL
PUMPING AGAINST A 5.5 METRE HEAD

BIN NO.	BIN INTERVAL	NUMBER OF REDUCED DATA SETS	BIN SAMPLE SOLAR RAD. KW/H ²	AVERAGE FLOW RATE L/HIN	STANDARD DEVIATION SOLAR RAD. KW/H ²	HEAT CSA HDBR REQUIREMENTS FOR FLOW RATE
1	0.00 TO 0.05	-	-	-	-	-
2	0.05 TO 0.10	-	-	-	-	-
3	0.10 TO 0.15	-	-	-	-	-
4	0.15 TO 0.20	-	-	-	-	-
5	0.20 TO 0.25	-	-	-	-	-
6	0.25 TO 0.30	-	-	-	-	-
7	0.30 TO 0.35	21	0.334	3.36	0.013	2.47
8	0.35 TO 0.40	23	0.375	18.27	0.011	6.60
9	0.40 TO 0.45	25	0.424	25.22	0.014	0.60
10	0.45 TO 0.50	37	0.474	26.42	0.016	0.78
11	0.50 TO 0.55	33	0.526	27.37	0.013	0.61
12	0.55 TO 0.60	51	0.574	27.68	0.015	0.83
13	0.60 TO 0.65	78	0.624	28.17	0.015	0.83
14	0.65 TO 0.70	87	0.675	28.36	0.014	0.76
15	0.70 TO 0.75	103	0.726	28.56	0.015	0.79
16	0.75 TO 0.80	97	0.774	28.75	0.014	0.73
17	0.80 TO 0.85	110	0.825	28.82	0.014	0.74
18	0.85 TO 0.90	125	0.875	28.81	0.014	0.78
19	0.90 TO 0.95	160	0.927	28.70	0.015	0.80
20	0.95 TO 1.00	200	0.977	28.73	0.014	0.80
21	1.00 TO 1.10	267	1.030	29.10	0.019	0.72
22	1.10 TO 1.20	2	1.150	29.44	0.017	0.06
23	1.20 TO 1.30	-	-	-	-	-

TOTAL NUMBER OF REDUCED DATA SETS: 1420
AVERAGE TEMPERATURE DURING THE TEST: 295.9 DEGREES KELVIN
AVERAGE WIND SPEED DURING THE TEST: 4.51 M/S

LETHBRIDGE WIND RESEARCH TEST SITE
SPECIFICATIONS and PERFORMANCE SUMMARY
1990 TEST SEASON

SOLAR PUMP NAME: **WARDUN**

SUPPLIER: Canadian
Agtechnology Partners

ADDRESS: P.O. Box 2457
Olds, Alberta, Canada
T0M 1P0

TELEPHONE: (403) 556-8779

PHYSICAL DESCRIPTION:

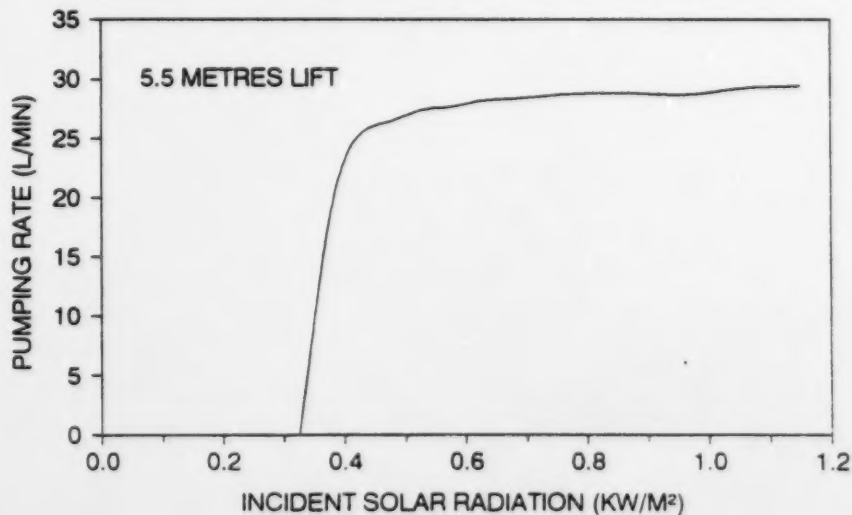
Number of Panels: 4
Panel Manufacturer: ARCO
Power Rating @ 25 C and 1000 W/m²: 43 W/panel
Configuration: parallel
Mount: fixed
Pump Type: helical progressing cavity

PERFORMANCE:

Testing Period: 50 days
Period Operational: 50 days
Percent Availability: 100 %

INSTALLED: August 9, 1990

1990 PERFORMANCE TEST RESULTS



METHOD OF BIN RESULTS FOR: CAP 2 PANEL
PUMPING AGAINST A 5.5 METRE HEAD

BIN NO.	BIN INTERVAL H/M	# OF DATA SETS	BIN SOLAR RAD. KW/M ²	FLOW RATE L/H	SAMPLE --SOLAR PANEL CURRENT AMPS	AVERAGE PANEL VOLTAGE VOLTS	POWER WATTS	FLOW RATE L/H	STANDARD DEVIATION --SOLAR PANEL CURRENT AMPS	STANDARD DEVIATION --SOLAR PANEL VOLTAGE VOLTS	POWER WATTS	FLOW RATE L/H	MEET CSA HDR REQUIREMENTS CUR-RENT AMPS	MEET CSA HDR REQUIREMENTS VOLT-AGE	POWER
1	0.00 TO 0.05	-	-	-	-	-	-	-	-	-	-	-	N	N	N
2	0.05 TO 0.10	-	-	-	-	-	-	-	-	-	-	-	N	N	N
3	0.10 TO 0.15	7	0.189	0.12	0.573	1.92	1.70	0.03	0.026	0.48	0.78	0.03	N	N	N
4	0.15 TO 0.20	47	0.230	0.37	0.698	4.17	3.29	0.27	0.053	1.34	1.14	0.27	N	N	N
5	0.20 TO 0.25	102	0.274	0.85	0.819	6.97	6.31	0.47	0.063	2.08	2.19	0.47	Y	Y	Y
6	0.25 TO 0.30	73	0.325	1.77	0.955	11.11	11.35	0.70	0.072	3.03	3.43	0.70	Y	Y	Y
7	0.30 TO 0.35	86	0.373	2.75	1.071	15.56	17.72	0.74	0.072	3.19	3.69	0.74	Y	Y	Y
8	0.35 TO 0.40	74	0.426	3.82	1.184	20.29	22.37	0.89	0.101	3.91	5.04	0.89	Y	Y	Y
9	0.40 TO 0.45	82	0.475	4.86	1.264	24.55	32.49	0.90	0.112	4.04	5.42	0.90	Y	Y	Y
10	0.45 TO 0.50	91	0.524	5.32	1.309	26.36	36.05	0.95	0.118	4.28	6.11	0.95	Y	Y	Y
11	0.50 TO 0.55	80	0.578	5.79	1.374	27.93	39.74	0.95	0.126	3.99	5.94	0.95	Y	Y	Y
12	0.55 TO 0.60	77	0.624	5.96	1.370	28.84	41.06	0.88	0.125	3.96	5.91	0.88	Y	Y	Y
13	0.60 TO 0.65	67	0.675	6.35	1.394	29.90	43.27	0.95	0.134	3.96	6.23	0.95	Y	Y	Y
14	0.65 TO 0.70	80	0.727	6.60	1.380	31.14	44.36	0.80	0.113	3.61	5.34	0.80	Y	Y	Y
15	0.70 TO 0.75	92	0.772	6.87	1.450	31.76	46.95	0.63	0.131	2.97	4.62	0.63	Y	Y	Y
16	0.75 TO 0.80	111	0.828	6.90	1.399	32.25	46.33	0.57	0.109	3.01	4.37	0.57	Y	Y	Y
17	0.80 TO 0.85	175	0.878	7.15	1.415	33.45	47.90	0.49	0.106	2.26	3.87	0.49	Y	Y	Y
18	0.85 TO 0.90	374	0.930	7.39	1.431	34.16	49.03	0.42	0.106	1.91	3.40	0.42	Y	Y	Y
19	0.90 TO 0.95	912	0.978	7.58	1.438	34.63	49.83	0.37	0.082	1.37	3.15	0.37	Y	Y	Y
20	0.95 TO 1.00	1780	1.034	7.57	1.449	35.15	50.96	0.39	0.081	1.26	3.59	0.39	Y	Y	Y
21	1.00 TO 1.10	126	1.128	7.74	1.547	35.54	55.02	0.32	0.100	1.34	4.27	0.32	Y	Y	Y
22	1.10 TO 1.20	6	1.220	7.83	1.653	33.42	55.25	0.10	0.073	1.87	3.19	0.10	Y	Y	Y
23	1.20 TO 1.30	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TOTAL NUMBER OF REDUCED DATA SETS: 4442
AVERAGE TEMPERATURE DURING THE TEST: 295.0 DEGREES KELVIN
AVERAGE WIND SPEED DURING THE TEST: 4.32 M/S

LETHBRIDGE WIND RESEARCH TEST SITE
SPECIFICATIONS and PERFORMANCE SUMMARY
1990 TEST SEASON

SOLAR PUMP NAME: CAP 2 Panel

SUPPLIER: Canadian
Agtechnology Partners

ADDRESS: P.O. Box 2457
Olds, Alberta, Canada
T0M 1P0

TELEPHONE: (403) 556-8779

PHYSICAL DESCRIPTION:

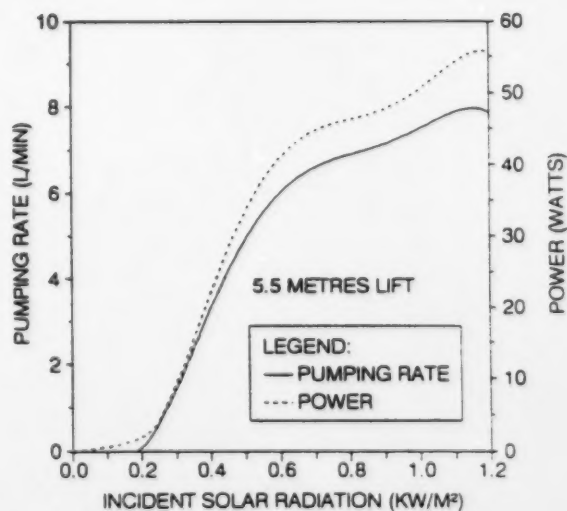
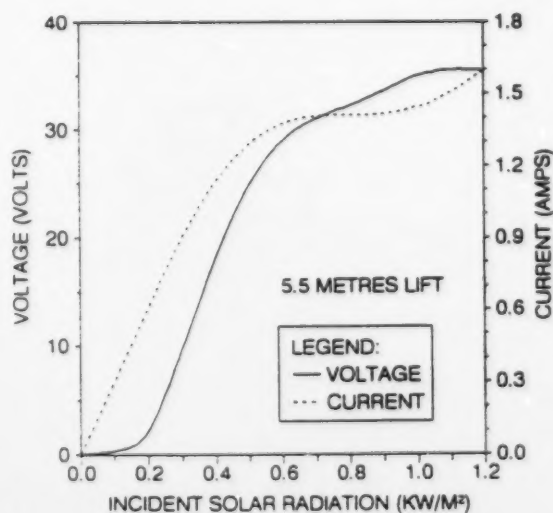
Number of Panels: 2
Panel Manufacturer: ARCO
Power Rating @ 25 C and 1000 W/m²: 47 W/panel
Configuration: series
Mount: tracking
Pump Type: 2 valve diaphragm

PERFORMANCE:

Testing Period: 206 days
Period Operational: 206 days
Percent Availability: 100 %

INSTALLED: May 30, 1989

1990 PERFORMANCE TEST RESULTS



METHOD OF BIN RESULTS FOR: CAP 3 PANEL
PUMPING AGAINST A 5.5 METRE HEAD

BIN NO.	BIN INTERVAL M/S	# OF DATA SETS	BIN SOLAR RAD. KW/H ²	SAMPLE FLOW RATE L/H	--SOLAR PANEL OUTPUT-- CURRENT AMPS	AVERAGE PANEL VOLTAGE VOLTS	OUTPUT POWER WATTS	FLOW RATE L/H	STANDARD DEVIATION --SOLAR PANEL OUTPUT-- CURRENT AMPS	DEVIATION PANEL VOLTAGE VOLTS	OUTPUT POWER WATTS	FLOW RATE L/H	MEET CUR- RANT RATE	MEET CSA REQUIREMENTS	MEET CSA VOLT-AGE	MEET CSA POWER
1	0.00 TO 0.05	-	-	-	-	-	-	-	-	-	-	-	N	N	N	N
2	0.05 TO 0.10	-	-	-	-	-	-	-	-	-	-	-	N	N	N	N
3	0.10 TO 0.15	-	-	-	-	-	-	-	-	-	-	-	N	N	N	N
4	0.15 TO 0.20	-	-	-	-	-	-	-	-	-	-	-	N	N	N	N
5	0.20 TO 0.25	3	0.232	1.08	2.150	1.72	5.67	0.85	0.110	1.01	3.41	-	N	N	N	N
6	0.25 TO 0.30	10	0.280	1.29	2.547	2.67	8.58	0.84	0.208	0.79	3.07	-	N	N	N	N
7	0.30 TO 0.35	15	0.323	1.82	2.845	2.74	9.85	0.92	0.177	1.42	5.46	-	N	N	N	N
8	0.35 TO 0.40	16	0.377	4.33	3.286	5.47	20.24	1.17	0.215	1.43	4.40	-	N	N	N	N
9	0.40 TO 0.45	24	0.424	6.21	3.698	7.69	30.70	1.33	0.353	1.46	5.86	-	N	N	N	N
10	0.45 TO 0.50	22	0.480	7.30	3.910	8.55	36.65	1.19	0.409	1.28	5.41	-	N	N	N	N
11	0.50 TO 0.55	18	0.524	7.81	4.094	9.08	41.74	1.30	0.407	1.74	7.08	-	N	N	N	N
12	0.55 TO 0.60	15	0.578	9.96	4.563	11.25	54.99	1.29	0.306	1.44	6.33	-	N	N	N	N
13	0.60 TO 0.65	14	0.620	11.18	4.691	12.27	59.25	1.13	0.216	1.12	6.44	-	N	N	N	N
14	0.65 TO 0.70	16	0.671	12.21	4.920	13.34	67.04	1.02	0.249	1.03	5.77	-	N	N	N	N
15	0.70 TO 0.75	17	0.730	12.05	5.058	13.35	69.15	0.88	0.204	0.79	4.12	-	N	N	N	N
16	0.75 TO 0.80	13	0.772	12.76	5.222	13.89	73.00	0.75	0.177	0.44	2.69	-	N	N	N	N
17	0.80 TO 0.85	16	0.826	12.95	5.182	14.02	73.14	0.77	0.223	0.41	4.42	-	N	N	N	N
18	0.85 TO 0.90	13	0.875	13.04	5.335	14.11	75.68	0.70	0.317	0.27	6.05	-	N	N	N	N
19	0.90 TO 0.95	18	0.927	13.03	5.346	14.37	76.85	0.87	0.273	0.27	4.55	-	N	N	N	N
20	0.95 TO 1.00	26	0.976	13.00	5.475	14.30	78.52	0.72	0.262	0.25	4.13	-	N	N	N	N
21	1.00 TO 1.05	23	1.019	13.60	5.513	14.56	80.39	0.67	0.262	0.31	3.44	-	N	N	N	N
22	1.05 TO 1.10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	1.10 TO 1.30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TOTAL NUMBER OF
REDUCED DATA SETS: 279
AVERAGE TEMPERATURE
DURING THE TEST: 294.9 DEGREES KELVIN
AVERAGE WIND SPEED
DURING THE TEST: 3.85 M/S

LETHBRIDGE WIND RESEARCH TEST SITE
SPECIFICATIONS and PERFORMANCE SUMMARY
1990 TEST SEASON

SOLAR PUMP NAME: CAP 3 Panel

SUPPLIER: Canadian
Agtechnology Partners

ADDRESS: P.O. Box 2457
Olds, Alberta, Canada
T0M 1P0

TELEPHONE: (403) 556-8779

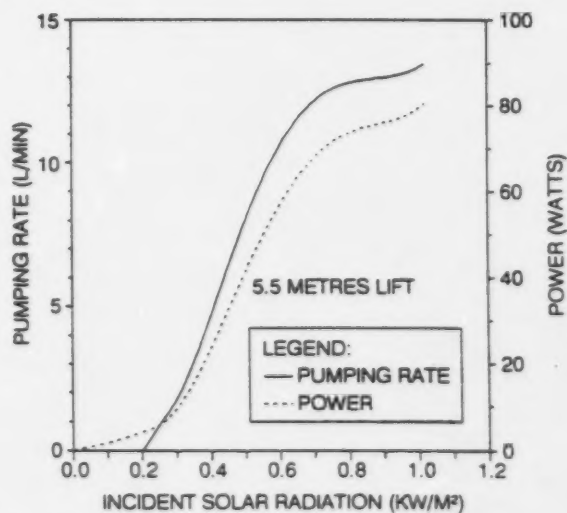
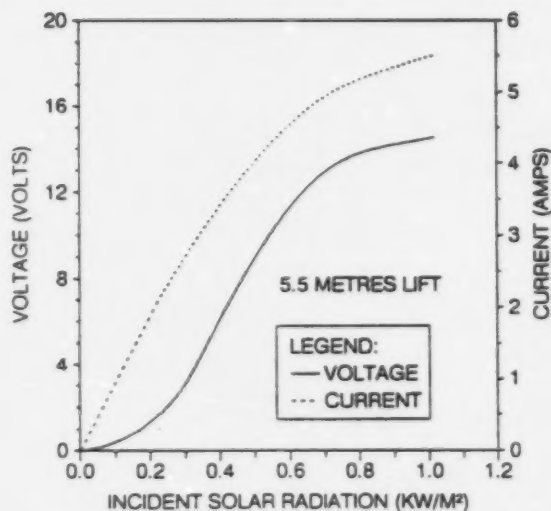
PHYSICAL DESCRIPTION:

Number of Panels: 3
Panel Manufacturer: ARCO
Power Rating @ 25 C and 1000 W/m²: 43 W/panel
Configuration: parallel
Mount: fixed
Pump Type: CAP F4 (4 valve diaphragm)

PERFORMANCE:

Testing Period: 50 days
Period Operational: 18 days
Percent Availability: 36 %
(Under Development)
INSTALLED: July 6, 1990

1990 PERFORMANCE TEST RESULTS



LETHBRIDGE WIND RESEARCH TEST SITE
SPECIFICATIONS and PERFORMANCE SUMMARY
1990 TEST SEASON

SOLAR PUMP NAME: CAP 4A Panel

SUPPLIER: Canadian
Agtechnology Partners

ADDRESS: P.O. Box 2457
Olds, Alberta, Canada
T0M 1P0

TELEPHONE: (403) 556-8779

PHYSICAL DESCRIPTION:

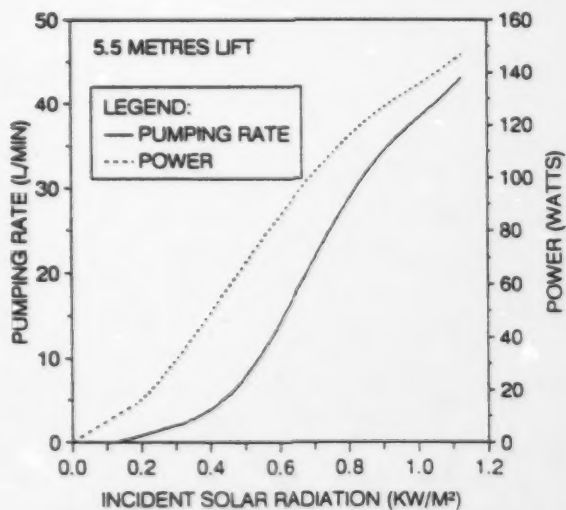
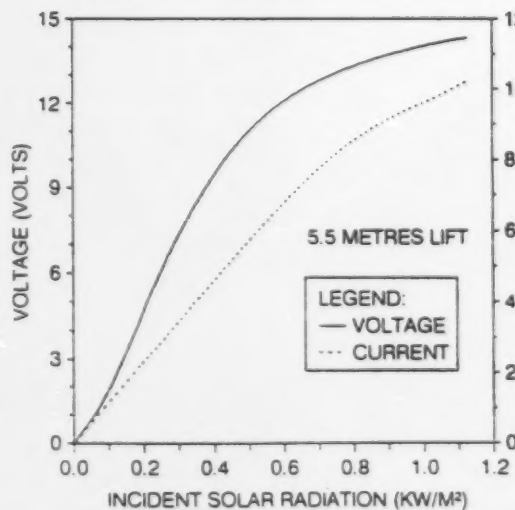
Number of Panels: 4
Panel Manufacturer: ARCO
Power Rating @ 25 C and 1000 W/m²: 47 W/panel
Configuration: parallel
Mount: tracking
Pump Type: centrifugal

PERFORMANCE:

Testing Period: 257 days
Period Operational: 257 days
Percent Availability: 100 %

INSTALLED: May 30, 1989

1990 PERFORMANCE TEST RESULTS



METHOD OF BIN RESULTS FOR: CAP 4B PANEL
PUMPING AGAINST A 5.5 METRE HEAD

BIN NO.	BIN INTERVAL H/S	# OF DATA SETS	BIN SOLAR RAD. KW/H ²	SAMPLE FLOW RATE L/H	--SOLAR PANEL OUTPUT-- CURRENT AMPS	AVERAGE VOLTAGE VOLTS	POWER WATTS	FLOW RATE L/H	STANDARD DEVIATION --SOLAR PANEL OUTPUT-- CURRENT AMPS	DEVIATION VOLTAGE VOLTS	POWER WATTS	MEET CSA MDRB REQUIREMENTS CUR- RENT VOLT- AGE POWER
1	0.00 TO 0.05	-	-	-	-	-	-	-	-	-	-	-
2	0.05 TO 0.10	-	-	-	-	-	-	-	-	-	-	-
3	0.10 TO 0.15	-	-	-	-	-	-	-	-	-	-	-
4	0.15 TO 0.20	-	-	-	-	-	-	-	-	-	-	-
5	0.20 TO 0.25	-	-	-	-	-	-	-	-	-	-	-
6	0.25 TO 0.30	-	-	-	-	-	-	-	-	-	-	-
7	0.30 TO 0.35	7	0.282	0.37	3.874	5.71	24.67	0.18	0.222	1.29	5.86	-
8	0.35 TO 0.40	11	0.334	0.57	4.724	9.05	43.41	0.31	0.082	0.41	2.14	-
9	0.40 TO 0.45	30	0.374	2.14	5.035	9.55	49.63	1.39	0.246	0.61	4.94	-
10	0.45 TO 0.50	27	0.424	5.15	5.693	10.73	62.84	1.77	0.299	0.67	6.00	-
11	0.50 TO 0.55	32	0.477	9.23	6.425	11.92	78.70	1.46	0.236	0.53	4.95	-
12	0.55 TO 0.60	21	0.529	12.26	7.020	12.77	91.62	1.97	0.274	0.48	5.60	-
13	0.60 TO 0.65	23	0.572	14.99	7.464	13.38	102.10	2.22	0.365	0.64	7.63	-
14	0.65 TO 0.70	17	0.627	19.22	8.233	14.36	119.33	1.95	0.312	0.39	7.11	-
15	0.70 TO 0.75	19	0.682	21.68	8.736	15.03	132.12	1.45	0.217	0.32	5.33	-
16	0.75 TO 0.80	14	0.727	23.45	9.082	15.41	141.17	1.25	0.182	0.30	4.72	-
17	0.80 TO 0.85	21	0.775	24.96	9.370	15.73	148.80	1.15	0.233	0.37	5.93	-
18	0.85 TO 0.90	16	0.824	26.23	9.690	16.11	157.04	0.93	0.180	0.25	5.21	-
19	0.90 TO 0.95	22	0.876	27.33	9.954	16.38	164.82	0.77	0.113	0.29	5.97	-
20	0.95 TO 1.00	29	0.924	28.19	10.135	16.60	169.08	1.10	0.227	0.29	5.97	-
21	1.00 TO 1.10	21	0.974	29.21	10.392	16.91	176.36	0.69	0.147	0.25	3.87	-
22	1.10 TO 1.20	21	1.029	30.09	10.699	17.33	185.49	0.43	0.175	0.23	5.40	-
23	1.20 TO 1.30	-	-	-	-	-	-	-	-	-	-	-

TOTAL NUMBER OF
REDUCED DATA SETS: 324
AVERAGE TEMPERATURE
DURING THE TEST: 318.0 DEGREES KELVIN
AVERAGE WIND SPEED
DURING THE TEST: 15.33 M/S

LETHBRIDGE WIND RESEARCH TEST SITE
SPECIFICATIONS and PERFORMANCE SUMMARY
1990 TEST SEASON

SOLAR PUMP NAME: CAP 4B Panel

SUPPLIER: Canadian
Agtechnology Partners

ADDRESS: P.O. Box 2457
Olds, Alberta, Canada
T0M 1P0

TELEPHONE: (403) 556-8779

PHYSICAL DESCRIPTION:

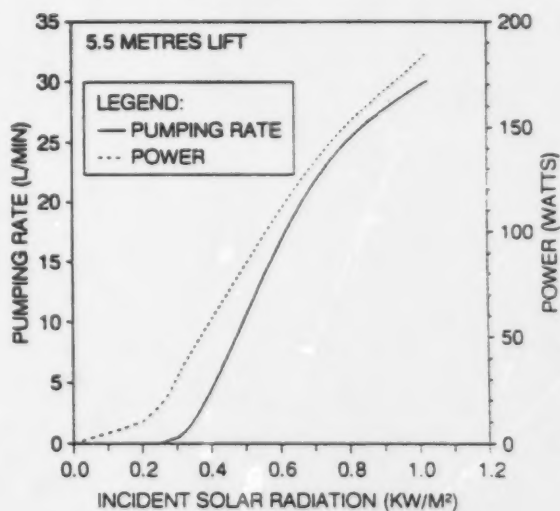
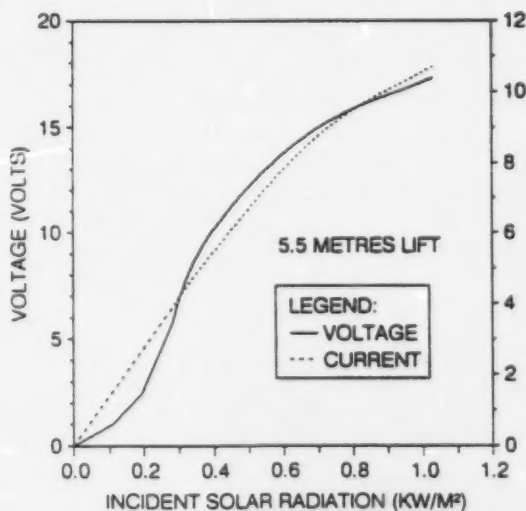
Number of Panels: 4
Panel Manufacturer: ARCO
Power Rating @ 25 C and 1000 W/m²: 55 W/panel
Configuration: parallel
Mount: fixed
Pump Type: centrifugal

PERFORMANCE:

Testing Period: 11 days
Period Operational: 11 days
Percent Availability: 100 %

INSTALLED: May 24, 1990

1990 PERFORMANCE TEST RESULTS



METHOD OF BIN RESULTS FOR: CAP 8 PANEL
PUMPING AGAINST A 5.5 METRE HEAD

BIN NO.	BIN INTERVAL	# OF DATA SETS	B I N SOLAR RAD. KV/M ²	S A M P L E FLOW RATE L/H	A V E R A G E PANEL OUTPUT-- VOLTAGE VOLTS	STANDARD DEVIATION --SOLAR PANEL OUTPUT-- CURRENT AMPS	FLOW RATE L/H	FLOW RATE L/H	STANDARD DEVIATION --SOLAR PANEL OUTPUT-- VOLTAGE VOLTS	POWER WATTS	FLOW RATE L/H	MEET CUR- RENT	MEET CSA HDRR REQUIREMENTS	MEET CSA HDRR VOLT-AGE	POWER
1	0.00 TO 0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	0.05 TO 0.10	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	0.10 TO 0.15	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	0.15 TO 0.20	7	0.182	1.21	6.10	0.445	0.83	0.83	1.64	9.89	0.83	N	N	N	N
5	0.20 TO 0.25	25	0.225	3.52	10.52	0.421	2.35	2.35	0.58	8.15	2.35	N	N	N	N
6	0.25 TO 0.30	21	0.278	10.52	12.44	0.432	2.25	2.25	0.63	9.81	2.25	N	N	N	N
7	0.30 TO 0.35	15	0.320	16.68	13.86	0.359	1.92	1.92	0.64	8.39	1.92	N	N	N	N
8	0.35 TO 0.40	9	0.372	22.28	15.27	0.323	2.16	2.16	0.57	11.01	2.16	N	N	N	N
9	0.40 TO 0.45	12	0.416	25.64	16.21	0.178	0.87	0.87	0.26	4.85	0.87	N	N	N	N
10	0.45 TO 0.50	12	0.476	28.56	16.98	0.173	0.51	0.51	0.21	4.86	0.51	N	N	N	N
11	0.50 TO 0.55	10	0.518	28.82	17.50	0.240	0.77	0.77	0.25	7.50	0.77	N	N	N	N
12	0.55 TO 0.60	12	0.571	29.36	17.74	0.348	0.29	0.29	0.31	7.67	0.29	N	N	N	N
13	0.60 TO 0.65	13	0.623	29.14	17.88	0.319	0.65	0.65	0.37	9.45	0.65	N	N	N	N
14	0.65 TO 0.70	6	0.663	29.53	18.33	0.299	0.09	0.09	0.36	9.57	0.09	N	N	N	N
15	0.70 TO 0.75	12	0.729	29.44	18.39	0.349	0.12	0.12	0.45	11.29	0.12	N	N	N	N
16	0.75 TO 0.80	10	0.773	29.36	18.09	0.367	0.14	0.14	0.51	12.40	0.14	N	N	N	N
17	0.80 TO 0.85	12	0.826	29.69	18.25	0.462	0.51	0.51	0.61	13.51	0.51	N	N	N	N
18	0.85 TO 0.90	11	0.878	29.76	18.09	0.395	0.51	0.51	0.52	13.27	0.51	N	N	N	N
19	0.90 TO 0.95	18	0.930	29.81	18.30	0.356	0.51	0.51	0.49	12.19	0.51	N	N	N	N
20	0.95 TO 1.00	23	0.978	29.77	18.32	0.432	0.42	0.42	0.58	14.80	0.42	N	N	N	N
21	1.00 TO 1.10	32	1.036	29.49	18.67	0.495	0.32	0.32	0.64	16.69	0.32	N	N	N	N
22	1.10 TO 1.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	1.20 TO 1.30	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TOTAL NUMBER OF
REDUCED DATA SETS: 260
AVERAGE TEMPERATURE
DURING THE TEST: 288.5 DEGREES KELVIN
AVERAGE WIND SPEED
DURING THE TEST: 5.69 M/S

LETHBRIDGE WIND RESEARCH TEST SITE
SPECIFICATIONS and PERFORMANCE SUMMARY
1990 TEST SEASON

SOLAR PUMP NAME: CAP 8 Panel

SUPPLIER: Canadian
Agtechnology Partners

ADDRESS: P.O. Box 2457
Olds, Alberta, Canada
T0M 1P0

TELEPHONE: (403) 556-8779

PHYSICAL DESCRIPTION:

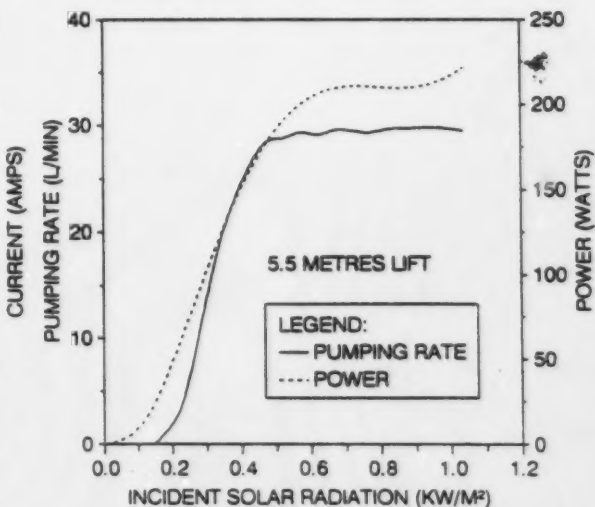
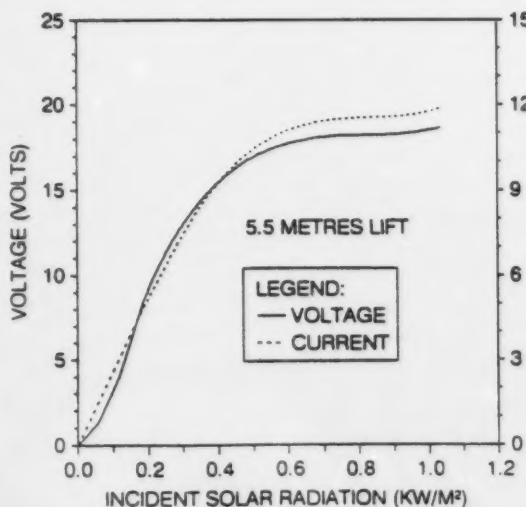
Number of Panels: 8
Panel Manufacturer: ARCO
Power Rating @ 25 C and 1000 W/m²: 55 W/panel
Configuration: parallel
Mount: fixed
Pump Type: centrifugal

PERFORMANCE:

Testing Period: 6 days
Period Operational: 6 days
Percent Availability: 100 %

INSTALLED: May 19, 1990

1990 PERFORMANCE TEST RESULTS



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5.0 ADDITIONAL CONTRACTS

5.1 Software for the Design of Stand-Alone Wind Systems

Over the past three years, the LWRTS has created a data base and software tool to assist in the design of stand-alone wind systems. The data base was created by analyzing 16 years of hourly wind speed data from 25 locations in the southern portion of the Canadian prairie provinces. The data base was published as a series of data tables which provided information on: (1) The distribution of wind speeds on a monthly, quarterly, and annual basis; and (2) The number of contiguous days below various threshold wind speeds on a monthly, quarterly, and annual basis. The latter set of tables was produced for return periods of 1:1, 1:2, 1:5, and 1:16 years. The tables provide sufficient information to determine the required size of a wind turbine and its associated storage system for a variety of applications.

The software tool was created in 1989 to simplify the utilization of the data book. The package (data and software) was written such that all audiences (users, distributors, manufacturers and designers) could utilize the material. For the software version, the user types in the potential wind turbine's performance curve (flow rate vs. wind speed), the flow requirements, the return period allowed for supplying a back-up pumping system and the wind speed characteristics at the site. The wind speed characteristics consists of all parameters available from the data book. Thus the user extracts the values from the data book, or determines his own similar type values. The program then determines the number of turbines required to pump the specified volume and the required size of the storage system. As with the data book, the design can be based on monthly, seasonal or annual periods and can cope with varying volume requirements. In 1990, the software underwent a major rewrite. It now has the additional capabilities of:

- 1) reading user generated wind speed distributions which are not required to fit the Weibull distribution.

- 2) providing pop-up help screens to assist the user in the usage of the software.
- 3) reading and writing all input and output files in ASCII text such that the user may edit the data sets with a simple text editor.
- 4) performing air density adjustments as requested by the user.

The package is presently being distributed by the LWRTS, with periodic seminars provided on its usage.

6.0 CONCLUSIONS

The test site evaluated eleven pumping systems from seven manufacturers in 1990. One windmill test site was vacant, while another had a windmill under construction for testing in 1991. Most of the tests performed were for the purpose of furthering the development of the machines. As a result, all the machines which remain for the 1991 test season are expected to undergo design changes.

The interest in the test site by manufacturers has continued to grow. They realize that field testing by an unbiased group provides a number of advantages. First, the data provided allows the manufacturer to further the development of their machines. Second, the reliability testing provides an indication whether the design is ready to be taken to the marketplace. Finally, the field testing at the LWRTS provides a good marketing tool by demonstrating their machines to large numbers of potential buyers which visit the site each year.

Interest by the Canadian International Development Agency (CIDA) has led to a request for evaluating two wind pumps in 1991 prior to shipping overseas. They have also indicated an interest in certifying the performance of photovoltaic pumping systems for export applications. It is anticipated that this type of certification work could assist in the cost recovery of the operations of the test site.

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